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HUMAN INTELLIGENCE AND COMPUTER PROGRAMS

Ed. by

O.K. Tikhomirov

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HUMAN INTELLIGENCE AND COMPUTER PROGRAMS

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CONTENTS

ANNOTATION

This book examines psychological problems associated with automation and mental labor. It describes the methods and results of experimental psychological investigations of the intellectual activity of an individual participating in a "dialogue" with a computer, and it discusses the prospects for bringing the potentials for man-made systems closer to those of human intelligence. The general psychological prerequisites for raising the effectiveness of automated systems are analyzed.

This book is intended for psychologists, philosophers, and specialists in automation of mental labor.

FOREWORD

Decisions of the 25th CPSU Congress have posed an important task--raising the effectiveness with which computers are used and broadening the range of their application. Naturally, various sciences can and must make their contribution to this complex task. However, the effectiveness of integrated research depends on how clearly the specific tasks of each scientific discipline are outlined. This is an especially important premise in relation to psychology, since the present practice is often to substitute the psychological approach by the information-and-cybernetics approach. As a consequence we must state the basic ways we are to use psychological knowledge in automation of mental labor, and we must formulate those problems of automation that are specific to psychology and which, when solved, would make application of this knowledge possible and effective.

One important direction for the use of psychological knowledge in automation is associated with one of the forms of computer application--the "dialogue" approach. As V. M. Glushkov noted, "further development of dialogue methods poses many technical and scientific problems. They pertain mainly to accounting for human psychology..." ((34, p 41). Consideration of the psychological features of human activity associated with writing (evaluating, improving) dialogue programs is a new area of applied psychological research. This is precisely why most of the attention of this collection is devoted to it. In order that human activity mediated by computer dialogue programs would be structured with sufficient effectiveness, these programs must be evaluated on the basis of not only logical and mathematical parameters but also the parameters of human creative activity. The possibility for posing new goals is one of the most important attributes of creative human activity capable of change, and this is precisely why we recommend interpreting change in goal formation as one of the concrete parameters to be used in evaluating dialogue programs. The program must be evaluated on the basis of whether or not it broadens the possibilities of goal formation. The study of new forms of human activity, mediated by computer programs and thus maximally "unburdened" of technical, "routine" operations, is one of the directions of applying psychological knowledge in practical automation.

The practice of building automated systems generally requires the use of psychological knowledge as well. Until recently the operator was the focus of the attention of psychologists concerned with the man-machine problem. Today, research on the activity of computer users (planners, scientists, managers, and so on) is acquiring ever-greater significance. I have formulated several psychological principles of the planning of man-computer systems oriented on such "users."

1. Satisfaction of cognitive needs. The range of changes occurring in cognitive needs must be considered when we select the information to be furnished to the individual by the computer. If it is difficult to determine the range of changes (in the case of purely creative tasks), the optimum strategy would be one in which the individual is given maximum freedom of selecting the information to be furnished by the computer, and of selecting the modes of computer use.

2. Enlargement of the creative components of labor. Such enlargement may be achieved by freeing the individual from routine operations. It is important in this case that he be freed of not the maximum but the optimum number of operations. "Overautomation" may disturb the system of human activity and reduce its effectiveness, rather than producing the expected growth in the creative content of labor. If we are to upgrade the quality and increase the speed of problem solving, we would have to study the factors affecting this process, and we would have to make sure that the data employed are complete and verified.

3. The possibility of voluntary regulation of information flows between man and computer. When using a computer, it is important to regulate the flow of information from the computer center, to personally monitor the work of the computer and, when necessary, to perform back-up calculations.

4. The unity of the principles of improving automated and unautomated control. The evaluated a person gives to information furnished by a computer depends on the content of this information, its correspondence or lack of correspondence with the user's previous experience, and the user's relationship to the computer and his relationship to other people (those transmitting the data for computer processing, and those servicing the computer). Mistrust of a computer may be based on a mistrust of other workers, and this is why automation must be tied in with improvements of management as a whole.

These principles, which I had formulated in the book "Man and Computer" in 1973 (105), were introduced into the practice of creating a concrete automated system owing to the initiative of L. M. Berger. His article, written together with B. K. Koshkin and contained in Part II of this collection, examines concrete problems concerned with implementing the psychological approach in automation practice; it is within the framework of this approach that the authors analyze "needs," "goal formation," and so on. Approximately the same theme can be found in the article by E. D. Telegina and L. A. Abramyan, who associate growth in the effectiveness of automated control with "the activity of the personality." Thus research described in the collection's second part is in a sense a continuation of the research described in "Man and Computer" (105).

Another direction for the use of psychological knowledge in the practice of automating mental labor is associated with determining the prospects of automation, the possibilities and means of bringing "artificial intelligence" based on computer programs closer to human intelligence. Our country's leading scientists hold different opinions on this question. In his report "The Scientific Problems of Developing Computer Technology" given at a jubilee session of the USSR Academy of Sciences, V. M. Glushkov worded the end goal of this development as "creation of artificial intelligence that is not only not inferior to, but which also greatly exceeds, in its capabilities, natural human intelligence. Although this goal is still rather far away, we are working toward it at full steam" ((34), p 41). The work he is referring to is aimed at raising the "intelligence level" of computers with the purpose of quickly raising the labor productivity of persons engaged in intellectual activities. In V. V. Chavchanidze's opinion "were we to have computer concepts at our disposal, we could cause an artificial conceptual intelligence to deal in deductive processes, including those of scientific and artistic creativity" ((101), p 219). A. M. Prokhorov states another opinion: "There is a fundamental difference between modern computers and the human brain. Its roots lie in the very foundation of these systems.... What is interesting is that attempts have been made to utilize some principles of living matter to build computers. This direction came to be called 'bionics.' However it has not as yet produced tangible practical results. Thus computer development is proceeding in its own unique direction, one which will continue to dominate in the near future" ((74), p 21).

The differences we find in the assessments of the prospects of automation stem, from my point of view, from differences in interpretation of human intelligence, and from whether the psychological characteristics of human intelligence are ignored or taken into full account, and therefore precise psychological definition of human intelligence is a priority prerequisite for scientifically grounded prediction of the trends in development of computer technology.

Materials pertaining to this range of questions are published in the collection's third part, which includes reports given at the All-Union Seminar "Psychology and Artificial Intelligence" in 1975. The points of view presented in these reports differ, which attests to the complexity and ambiguity of these problems. I believe that the main prerequisite for effectively developing all three directions is to study the unique qualitative features of human thinking in comparison with computer information processing. Such research is precisely the main psychological problem with which efforts at automating mental labor are concerned. Therefore we must dwell on it in greater detail.

Both "artificial intelligence" specialists and psychologists sometimes ignore the unique qualitative features of human thinking. "In relation to artificial intelligence, the question as to what is doing the perceiving and what is doing the thinking--man or machine--is unimportant. This is an insignificant detail," writes N. D. Nil'son (62). At the same time the formula adhered to by positivistically oriented psychologists, "intelligence is that which is measured by intelligence tests" ((130, p 588), offers support to those who are prepared to interpret cases of computer solution of some problems as evidence of the computer's "intelligence."

We often encounter the following assertions in the literature: "Creativity is information processing" (57), "Thinking is a random process," "The essence of thinking lies in construction of a model of the outside world," and "Invention algorithms do exist" (7). The information theory of thinking, which is sometimes called the "modeling" theory, having in mind mainly semeiotic models, has taken shape. In my opinion any comparison of an information theory of human intelligence with a psychological theory must include a comparison of the realities described by the terms "psychological reflection" and "intellectual activity" on one hand and the terms "model" and "information processing" on the other, as well as the revelation of qualitative differences between them.

A distinction is made in A. N. Leont'yev's work between a sensory image and a model. The unique features of a sensory image are activity (interest) making deeper penetration into reality possible, objectivity, and participation of effector units in the arisal and operation of the image (56).

In addition to reflecting the world in the form of sensory images, the human mind can reflect at a thinking level, which is also typified by objectivity. What we usually encounter is not individual objects but entire objective situations, which include complex mutual relationships and interactions among objects. Activity, interest, and selectivity are also inherent to mental reflection, but in this case they assume a specific form of manifestation. A mental image also requires effector units for its development, which can be seen especially clearly in cases of active visual thinking, though it may also be discovered at the level of verbal thinking (objective manifestations of internal speech).

"Artificial intelligence" specialists are interested in human thinking mainly as a problem solving process. Turning to this particular case, we must distinguish between initial, final, and intermediate reflection of the problem by the subject (that is, its conditions and requirements). It should be noted that activity is inherent to initial reflection of the conditions of the problem. As experiments by V. Ye. Klochko (53) showed, when subjects first acquaint themselves with the conditions of a new problem they prepare themselves in a certain way for formulation of a particular goal, one which sometimes anticipates and even displaces the goal formulated by the experimenter. "Initial orientation in an assignment" (this is what we sometimes call this process of initial reflection) may be very heterogeneous in terms of its psychological structure.

Human mental reflection includes within itself both conscious and unconscious elements including generalization. It is typified by operational and personal meanings of complex dynamics. As was demonstrated by I. A. Vasil'yev's research (25), operational meanings transform into personal ones during solution of a particular problem. These unique features of real human thinking, in particular, are not accounted for by the "modeling" theory, and thus development of artificial systems satisfying the requirements of modeling theory would not mean re-creation of human thinking.

The qualitative differenc between human thinking and computer "information processing" is expressed in the description of the former as the activity of a subject. As with all other activity, human thinking is the product of human needs and models. Developed forms of thinking are typified by the presence of special cognitive needs and a specific "object" with the help of which the range of needs for knowledge is satisfied. These needs are not only a prerequisite of mental activity, and they are not only transformed after the completion of mental activity;

they also arise and undergo modification in the course of solution of a concrete problem. New goals arise on the basis of cognitive needs. The goal forming process, various forms of which are examined in a special paper (76), is one of the most important characteristics of real human thinking. During his activity, man makes various evaluations expressing the relationship between the results attained (or anticipated) and the motives of activity. These evaluations may be emotional, they may be verbal-logical, and they perform a role in internal regulation of activity. Research by Yu. Ye. Vinogradov (75,76), I. A. Vasil'yev (25), and V. Ye. Klochko (53) showed that solution of subjectively complex problems would be impossible without emotional regulation, though presence of such regulation does not guarantee attainment of an objectively valid result. Research has revealed the existence and the great role played by emotional anticipation in the solution of complex problems. If we are to arrive at an objectively valid solution to a problem, we would have to achieve coincision of subjective and objective value characteristics; if they do not coincide, the problem will not be solved. At certain stages of the search for the solution contradictions may arise between emotional evaluations (manifested in involuntary reactions of the body) and verbal evaluations (right, wrong) of certain intellectual acts, in which case the emotional evaluations sometimes do in fact have greater validity. If the latter are dominant in such cases, the activity leads to an objectively valid result (75). It has been demonstrated that intellectual emotions play a part in all stages and levels of goal formation, and that revelation of the unverbalized operational meaning of elements within a situation is a prerequisite of the arisal of intellectual emotions (25). Emotional anticipation may also alter the structure of the problem solution process.

All activity includes technical procedures (operations) within itself. Efforts at creating "invention algorithms," "techniques of invention," and so on are essentially based on the failure to distinguish between activity and operations. The procedures by which we transform objects are a part of creative activity, but they are not all of it. The expression "algorithm" often bears a metaphoric nature, and it may be used in relation to a program of planned, directed actions ((8), p 101); it is sometimes even used synonymously with the expression "stages of activity." However, it misleads engineers who have become accustomed to viewing the algorithm as a formalized procedure guaranteeing a solution. We must clearly see that instructions such as "study the principal technological sectors," "study the subordinate technological sectors," "gather information on ways for solving technical problems, on physical effects, and on new materials," "learn creative decision making," and "correctly state the problem" resemble the instructions of an algorithm in outward appearances only.

We should make note of the conceptual relationship between psychological problems associated with "artificial intelligence" and those associated with "dialogue." "Dialogue" interaction between man and computer may be described at two levels: the information level and the psychological level. At the information level, interaction is typified by the form of the symbols employed, their sequence, and the speed at which they proceed from machine to man and from man to machine. At the psychological level, interaction is once again typified by the goals for the attainment of which the individual communicates with the computer, and by transformation of goals under the influence of the information obtained, the meaning it has to the individual, and the evaluations (including emotional ones) made by the individual of both the overall capabilities of the computer and of the solutions of concrete problems. The same symbols, presented to the user in identical form and at identical speed, may be evaluated, understood, and employed differently depending on the concrete situation, on the overall state of the individual, and on the goals and motives of his activities. Given constant information interaction between man and computer, the psychological interaction will vary.

This difference is not accounted for (it is ignored) in the information-and-cybernetics approach; however the studies published in this collection show that if we do not account for it, we cannot evaluate and effectively build dialogue programs. Psychological research on the activity of an individual engaged in a dialogue with a computer must rely first of all on the general psychological theory of activity and on psychological research on creative thinking based on this theory. Paradoxical though it may seem to specialists in computer technology, were we to define engineering psychology as the study of the interaction between man and machine through information, as is often done, we would not be able to achieve effective development of dialogue programs on the basis of engineering psychology since we must consider a broader range of factors than just information interaction alone.

If we are to reorient research from the "operator" to the "user" of automated systems, we would also need to differentiate more clearly between the engineering psychology approach and the psychological approach itself; it would require consideration of the specific qualitative features of man for the creation of man-computer systems, and it would necessitate our not limiting ourselves to superficial analogies between man and machine in our descriptions of information flows in an existing (and in a planned) system.

Thus no matter which of the three named directions we take in our effort to automate mental labor (creation of "artificial intelligence" models, planning and evaluation of the effectiveness of automated control systems, construction of effective dialogue systems), we would have to account for the psychological features of human thinking, and human activity as a whole. Naturally these must become the object of further, deeper research.

Expansion of man's intellectual potentials is associated today by many psychologists with assimilation of the logical apparatus (concepts, the methods of logic) and with increasingly fuller (more "rigid") control of the process of assimilating this apparatus. Thinking formed in this way is said to be more sophisticated than creative, independent, intuitive thinking.

The use of computers opens a fundamentally new way for broadening the intellectual potentials of the individual--that of unburdening him of formalized, logical procedures, and permitting him to utilize such procedures without having to assimilate them. Let me clarify this idea with an example. We could get an individual to assimilate a certain algorithm, and then assert that from here on in, no more errors would be made in solving problems of a certain class, and that the problems would be solved faster and on a more general basis. The second way is to solve the problems utilizing an algorithm already contained within a computer program, without having to assimilate it. The advantages of the second way lie in the fact that the algorithm may be implemented significantly faster and that the complexity of the algorithm itself could exceed the practical capabilities the individual has for assimilating this algorithm.

In psychology, we commonly distinguish among three types of thinking--visual-active, visual-descriptive, and verbal-logical. How, then, do we define thinking mediated by computer programs? It appears to me that in application to verbal-logical thinking, we need to differentiate between two of its variants--thinking mediated by logical procedures outside of the subject, and thinking mediated by internal logical procedures--that is, by assimilated concepts and methods of logic. Thinking mediated by computer programs is the most complex form of externally mediated verbal-logical thinking. Analysis of this sort of thinking is a new task of general psychology, posed to it by the practical problems of automating mental labor.

The collection offered here to the reader was prepared in conjunction with the scientific research program "Psychological Problems of Creating and Using 'Artifical Intelligence'" organized by the Scientific Council for the Problem "Artificial Intelligence" of the USSR Academy of Sciences Presidium Committee for Systemic Analysis. Books published previously in this series include "'Artificial Intelligence' and Psychology" (50) and "Psychological Mechanisms of Goal Formation" (76). Naturally, not all of the psychological problems of automation were illuminated in this collection. Problems such as the use of computers in training and in psychological experimentation, and the plans for intracerebral use of computers (152) require special discussion.

PART I
PSYCHOLOGICAL PRINCIPLES OF DIALOGUE SYSTEMS

INTELLECTUAL ACTIVITY IN A 'DIALOGUE' WITH A COMPUTER

O. K. Tikhomirov, I. G. Belavina

Interaction between man and computer is presently being examined in different aspects--technology, mathematics, engineering psychology and general psychology. This paper is an attempt to approach study of the activity of the user of "man-computer" "dialogue" systems from the positions of general psychology. Work in this direction is already going on (79). Its main purpose is to study and develop the methods of teaching system users the formal resources of solving problems with the assistance of a computer.

In foreign studies, this direction is also broadly represented in the planning of teaching systems intended to train all persons who, by the nature of their activity, use computers for, as an example, several hours a day. These include all sorts of ticket agents, bank workers (clerks), secretaries and so on. In the opinion of many prominent specialists in computer technology (59,72), however, it would be impossible to teach all interested persons programming skills. They may include, for example, directors of large companies, engineers, designers, planners, physicians, teachers and so on. Besides people possessing programming skills, there has recently appeared another category of persons who use ready-made programs and computer resources but do not possess programming skills. It has been noted that this category is becoming the largest and that it is constantly expanding as more specialists from different areas of science and public services join it (36,71).

The importance of research on the psychological factors associated with man's interaction with ready-made computer programs can be explained by the fact that the effectiveness of computer use in the "man-computer" systems existing today, created for joint solution of problems, is not very high (59,72). Cases are known in which the overall effectiveness of a "man-computer" system has been reduced by hundreds and even thousands of times because of imperfections in programs or poor organization of problem solving with the computer (34). This is an indication that either the individual fails to utilize all of the advantages offered to him by the computer, or he refuses to use them at all. As a rule the important role of psychological principles in development of "dialogue" programs is understated.

We turned to laboratory experimentation to study the unique features of the intellectual activity of an individual solving problems with a computer in "dialogue" mode. We did so because, first of all, "dialogue" systems are still just undergoing creation, and there are difficulties in conducting research with real systems; second, laboratory research opens up possibilities for more-analytical study of activity, and development of some general recommendations for planning real "dialogue" systems.

We chose goal formation as one of the principal parameters describing intellectual activity, since goal formation is a particular manifestation of the creative nature of activity. By doing so, we were able to maintain a specifically psychological approach (in distinction from an information-and-cybernetic approach) to man's interaction with a computer.

The research objective was to develop a procedure for studying "dialogue" activity, conduct the experimental studies themselves and discuss, on the basis of these studies, the principles of writing "dialogue" programs and the activity of an individual using these programs. This was essentially the first elaborate laboratory experimental study of intellectual activity in "dialogue" mode. Naturally, therefore, it was exploratory in nature.

§1. The Methods of the Experiment

Game Analysis

"Kalah," a zero-sum game for two persons (one player wins and the other loses), was used to analyze goal formation by individuals in a "dialogue" with a computer.

Each player possesses six playing fields, 36 counters (stones) and one "kalah" field in which the player must collect his counters.

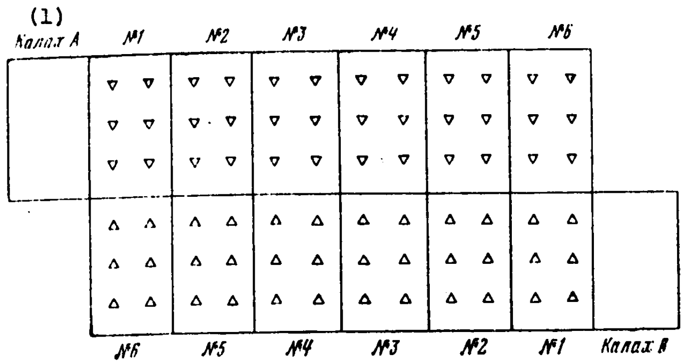
In the "kalah" fields, counters can only be accumulated; these fields and the 12 other playing fields create the objective conditions of the game.

The counters are distributed evenly among the six fields (positions), which are numbered as shown below.

The fields of the rivals are opposite one another; moreover each player has his own special field, called the "kalah," next to the first playing field.

When his turn comes up, the player removes all counters from one of his fields and redistributes them, placing one in each of the other fields in decreasing order of field number, to include his "kalah." If there are any counters left over, they are distributed in the opponent's positions (in order of their decreasing number); if more counters are still available, these are distributed once again in the player's positions, bypassing the opponent's "kalah."

Rule 1. If the last of the distributed counters falls into the player's "kalah," he gets one more move. In all other cases it becomes the opponent's turn.



Калах A	№ 1	№ 2	№ 3	№ 4	№ 5	№ 6	
0	6	6	6	6	6	6	
	6	6	6	6	6	6	0
	№ 6	№ 5	№ 4	№ 3	№ 2	№ 1	Калах B

Figure 1. The Starting Situation of "Kalah": *a*) situation on the board; *b*) numerical description of the situation

Key:
1. Kalah

Rule 2. If the last of the distributed counters falls in one of the player's empty positions and the opponent's opposite position is not empty, the contents of these two fields are moved to the "kalah" belonging to the player making the move, and it becomes the opponent's turn.

Rule 3. If there are no counters in the player's positions, then all counters in the opponent's positions are moved to the opponent's "kalah," and the game ends.

In all cases the individual who collects more than 36 counters in his "kalah" wins. In the "kalah" positions counters can only be accumulated; therefore a win can be determined from the ratio of counters in the "kalah" positions of the players without playing out all of the counters.

The end goal of the game is to accumulate the maximum number of counters in one's "kalah." The players move in turn; however, the rules of the game permit several moves in a row by one of the players, if the counters in his six positions create a particular situation. The arrangement of counters among the fields of the subject and the fields of his opponent is what creates the concrete game situation. In the initial situation the arrangement of the counters is always the same: The "kalah" fields of the players are empty. The game can be started by either of the players.

The counters are moved among the fields in the same direction (counterclockwise). Each move produces a specific result--a change in the game situation. Each move may perform either one or several functions depending on the concrete conditions of the particular move. The principal functions are: protection, capture, entrapment and simple accumulation of counters in a "kalah."

Figure 2 shows a game situation illustrating the functions listed above.

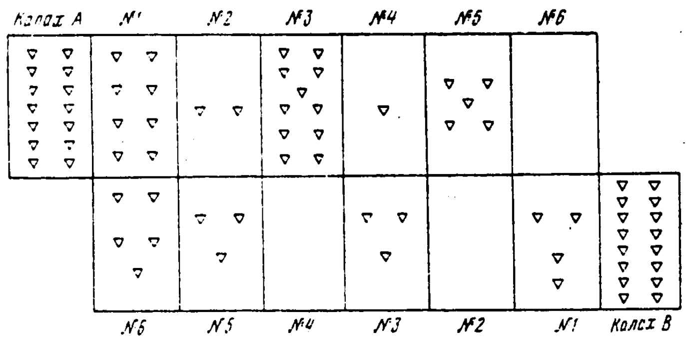


Figure 2. An Intermediate Situation in "Kalah" Illustrating the Principal Functions

Player A exercises a protective function when he moves from field five to field two. If player A fails to remove his counters from field five, in his next move player B would be able to take these five counters from field five and place them in his "kalah." Then the ratio of counters in the "kalahs" of the player and the opponent would be 15:22--that is, clearly not in favor of player A.

A capture function is exercised when player A moves from field one to his own field six; in this case the number of counters in player A's "kalah" increases by seven.

A trap forms when player A moves from field three and player B fails to move from field four.

Simple accumulation of counters in player A's "kalah" is achieved by moving from field two or field five.

The objective functions of a move may be interpreted as the strategic goals of the player. The functions of protection and capture are analogous to those functions in chess. Accumulation of counters in a "kalah" may occur quickly when the subject fails to capitalize on the remaining functional possibilities offered by the concrete situation, or when the conditions of the task themselves prevent the subject from doing so. A move made with the purpose of entraping the opponent is preparatory to a certain change in the game situation leading subsequently to capture.

Change in the game situation may be dependent and independent of the subject. An independent change in the conditions of the task (the game situation) would be a move by the opponent (player B) which might reduce the subject's possibilities for implementing his planned actions--for example preparing for and exercising the capture function. Each concrete move, which can lead to a particular result, is characterized by the strength parameter. In the game of "kalah" (as is the case, for example, in chess), we can distinguish parameters such as the strength and value of results. A strong move, for example, would be one in which counters are taken from one of the opponent's fields. The strength of a move is gauged in relation to the scale of value of the results to which it leads. Thus moves in which counters are taken and quickly accumulated and a move creating a threat to the opponent are strong moves.

The value of a game situation depends on both the number of the playing field and the quantity of counters it contains. As an example the closer the playing field is to the "kalah"--that is, the lower its number, the higher is its absolute value from the standpoint of the possibilities for counter accumulation. However, this absolute value is not always consistent with relative value. The relative value of an element depends on the concrete conditions, particularly on the ratio of counters in the fields, while the strength (value) of a concrete practical move depends on relative value, which is governed by the absolute value of the field and the number of counters.

We can distinguish among game situation parameters defined by the concrete conditions (unique features) of a position. A player's position may be strong, weak, good, bad, or neutral.

When playing to win, the subject considers several things in choosing his best move. The process of choosing such a move can be described as the setting of goals having a hierarchical structure and corresponding: a) to attaining the end result--that is, winning; b) choosing a particular type of strategy; c) finding those tactics which would support the chosen strategy. Goals associated with directed transformation of the game conditions can be called strategic. Three types of such goals can be distinguished in the game of "kalah."

Type 1--creating a trap for the opponent. By reaching a type 1 goal the subject is able to gain a certain material advantage. The extent of this material advantage depends on the nature of the game position. Thus when the game position is good, a significant material advantage can be achieved. A material advantage close to a type 2 goal can be achieved from a poor game position.

Type 2--fast accumulation of counters in the "kalah" in accordance with rule 1. Achievement of this goal permits the player to make several moves in succession leading to a material advantage, though of course lower than in the case of type 1 goals, since the number of counters in the "kalah" is increased by one in each move.

Type 3--hindering the opponent from reaching type 1 and 2 goals. Attainment of such goals requires development of certain tactics, which may in principle be associated with tactical goals.

The choice of a concrete move depends on parameters of the game situation such as, for example, the evaluation reached by summation of the relative evaluations of the elements of the game situation.

Characteristics of Computer Messages

It is not hard to learn to play "kalah." The rules of this game are simple, but at the same time it is not a trivial game. Moreover it is easier to describe it in formal terms for programming purposes than it is to describe chess. The first program for the game of "kalah" was written by (Rassel) in 1964 (62). (Sleygl) and (Dikson) described experiments with the game "kalah" in 1969 (86). Similar experiments (an individual playing against a computer) were performed by Rechenberg (151). However, the experiments conducted by Sleygl, Dikson and Rechenberg were basically aimed at studying the possibilities of a computer to model natural intelligence. It was not the goal of the authors to study and create situations involving joint solution of problems by a person and a computer.

In our research the game of "kalah" is used for laboratory analysis of the activity of subjects participating in a dialogue with a computer in a language close to a natural language (Russian), with the computer acting as an "adviser." Our goal was to develop a procedure of experimental psychological research which would allow us to study the conditions for creating and using effective dialogue programs. The corresponding methods of describing the game of "kalah" in formal terms permit creation of strong programs that can stand up to human intelligence (62,86,151). To select a move (the best possible), the computer builds a decision (game) tree and sorts through the possible variants on the basis of their heuristic evaluation. This is done using a system of formalized evaluation criteria, the values of which can be determined in the following fashion. One of the evaluation methods is the minimax procedure, used to calculate the best maximum evaluation of one player (in artificial intelligence systems, this would be the computer) and the best minimum evaluation of the other player (in artificial intelligence systems, this would be the person). The decision tree reflects the possible plays of the partners, and it is characterized by the number of successive moves of the player and opponent (by the depth of the tree). As the depth to which the possible moves of both players are considered is increased, the tree tends to branch out laterally. Therefore in order that the computer could predict the moves of the player and the responses of his opponent, heuristic programming methods must be used. A literature analysis showed that in game programming, there are no unambiguous heuristic techniques applicable to even one game (for example the game of "kalah"). Programs created by different authors differ from one another in relation to the potentials of computer prediction, the ability of a person to win a game in a certain amount of time, and so on. In our study, the program for the game of "kalah" was written in two phases. The first phase was based on decision tree building methods described by (Dzh. Sleygl) (85) ("first in depth" and "first in breadth").

Next we modified the first decision tree building variant on the basis of a special analysis of the game, which revealed to us a certain group of heuristic arguments. A certain set of strategic goals and tactics that would help the individual to win was introduced into the program (16). This approach was significantly different from approaches typical of modeling natural intelligence. Programs created in support of this method gave the individual certain advantages: The computer played not against the individual but in his behalf, serving as a partner and "adviser" in joint decision making. By reorienting the program for joint decision making, we were able to allow the subjects to make two forms of predictions relative to changes in the game situation: those dependent on player A, and those independent of him (actions of player B).

Thus in our method the computer was used as a tool in support of a certain form of the individual's activity concerned with solving problems of complex content.

Three forms of computer messages are used in the organization of the dialogue between man and computer. The first form consists of basic messages. They contain information on the game situation, and their content reflects, to a certain degree, the qualitative features of goal formation depending on the computer program variant employed. The second and third form are used to organize the dialogue between man and computer (first function), to record certain elements of this interaction (second function), and to automatically record some parameters of joint decision making (third function).

The method permits use of two variants of programs for the basic messages. The composition of the basic messages (the first form of messages) was determined by the research objectives. Three classes of messages were developed for the first variant. They are oriented upon the results of a move, its evaluation and the possibilities of achieving strategic goals and implementing tactics promoting victory. These messages corresponded to certain classes of goals determined for the game of "kalah."

The first class: messages having to do with the properties of a concrete game position (GP) and recommending the best move.

The second class: messages having to do with some general possibilities for achieving strategic goals (SG).

The third class: messages having to do with some of the tactics of achieving certain strategic goals (TA).

Messages of the first class are subdivided into five types.

1. Messages directly stating the move of the principal player that would be most preferable in the given situation. If several moves of equal value are possible, they are all considered in the computer message. An example of a message of the first type (for the game situation shown in Figure 2) would be: "The best move is from field 1" (GP1).

2. Messages containing an evaluation, expressed in numerical form, of a move that has already been made by the principal player and which therefore cannot be rescinded (GP2). An example for Figure 2 would be: "Evaluation of the move you made yourself: 0072" (Before the game began, the manner in which the computer calculates the evaluation in arbitrary points and the fact that the range of evaluations varies from 0 to 1000 were related to the subject in his instructions).

3. A message taking the form of a set of evaluations--numerical values assigned to each of the six fields for the given game situation (GP3). They are calculated by the computer for the last depth level for the first program variant, 5. Thus at depth 5 the computer tree contains 7,776 game situations reflecting the consequences of moves from all six fields; following certain heuristic rules, the computer evaluates groups of game situations representing the consequences of just a single initial move. The heuristic arguments also include certain features of the game such as the locations and numbers of counters in the fields and the ratio of counters in the "kalah" fields belonging to player A and player B. That group having the highest

value is said to be the best. In distinction from a GP1 message, a GP3 message not only contains information on the best move (the maximum evaluation), but it also provides a numerical description of all moves possible in the given situation. An example for Figure 2 would be: "The evaluations of your positions are as follows: 784 413 396 380 472 99." This means that, for example, a move from field No 1 is evaluated by the computer as 784 points while a move from field 6 is worth only 99 points.

4. A message containing an evaluation of a move made by the opponent in a given concrete situation (GP4). An example for Figure 2 in a case where the opponent moves from field 3 would be: "Evaluation of the move made by the opponent--036." This message is similar to a GP2 message.

5. A message consisting of two parts: A GP3 message and a message indicating how frequently the computer encountered a maximum evaluation when it calculated the evaluations of all possible variants of the game situation in one group or another (GP5). To calculate the evaluations given in a GP3 message, the computer examines all 7,776 game situations. Dividing them into groups of 216, the computer simultaneously calculates the number of maximum evaluations encountered in each of the six groups. Thus, for example, if evaluations of equal or close value are encountered, the subject may base his choice of moves on additional information indicating how frequently such evaluations are encountered. If the frequency of a high evaluation is large, this means that a move from the first field would be strong. An example of a GP5 message would be:

"Evaluations of your positions are:	784	413	396	380	472	99."
"Frequency of evaluation:	2	2	3	3	2	4."

In this case the move with a maximum value of 784 and a frequency of 2 is the best.

Messages of the second class actually contain the generalized characteristics of the game situation at hand, permitting or not permitting the player to set the following four strategic goals that may be attained at depth 5--that is, with his third move (SG).

1. A message indicating player A's (the subject's) possibility for collecting his opponent's counters in his own "kalah." Such an action is equivalent to an attack on the opponent.

2. A message indicating whether or not the opponent could be prevented from collecting the subject's counters in his "kalah," or a message indicating the opponent's possibility of moving into his "kalah."

3. A message indicating the subject's possibility, or its absence, of moving into his "kalah." An example of an SG message would be: "In your situation you cannot prevent the enemy from moving into his 'kalah'."

Messages of the third class contain a description of tactical goals leading to victory.

1. Selecting your move in such a way that the maximum number of your counters would fall within your fields. One of the results of reaching this goal is preventing the appearance of additional counters in the enemy's fields, so as to permit collection of all of your counters in your "kalah" at the end of the match, or to keep the opponent from creating a threat.

2. Selecting the next move in such a way that the opponent would not have any empty fields left. By reaching this goal, the subject is able to avoid the threat of an opponent wishing to reach his goal of "collecting the counters of the main player in his 'kalah'."

3. Selecting the next move in such a way as to permit placement of your last counter in the field closest to your own "kalah" field. By reaching this goal, the subject is able to move into his "kalah"--that is, achieve the goal of accumulation.

4. Preventing accumulation of a large number of counters in one field. Attainment of this goal permits the subject to avoid a threat from the opponent.

5. Selecting the next move in such a way as to accumulate 13 counters in some one field. Attainment of this goal would allow the subject to subsequently reach the goal of "collecting the opponent's counters in his 'kalah'."

6. Selecting your move in such a way as to accumulate, in one of the fields, a number of counters equal to the sum of 13 plus the field number. Attainment of this goal would permit the subject to move into his "kalah." These messages were all presented together irrespective of the concrete situation. Certain messages in the list, for example 4 and 5, contain conflicting information, such that the subject was able to select the best strategic goal in the given game situation.

In the second variant of the "dialogue" program the basic messages were developed on the basis of content analysis of the goal formation processes carried out by a subject solving a problem in "dialogue" interaction with the computer, using the formalized resources offered to him by the computer. The means of describing computer information and transferring it to man were reworked on the basis of the laws characterizing the psychological features of joint problem solving, revelation of which became possible only owing to the use of the first variant of the programs. Moreover the psychological features of solving the type of mental problems under consideration here made it necessary to supplement the formal methods of building the game tree in the computer memory. Additional heuristics were introduced into the program, making it possible to increase the depth of game tree construction from 5 to 8 in the same computer time. In this variant there are eight types of messages providing concrete data on the material advantages of one player in relation to the other and on the possibilities the player enjoys for reaching his generalized strategic goals. The goals were general in nature in that the computer indicated the number of threats and the number of moves into the "kalah" of the player or opponent from some initially selected field X in the given game situation, rather than a concrete message describing the possibility or impossibility of making some particular moves. Reorientation of the computer messages not only toward the end result but also toward the intermediate stages of problem solution made it possible to organize more-flexible interaction between man and computer.

The content of the basic messages in the second variant was determined in accordance with the depth of the subject's analysis of the game situation.

A IA (IB) message contains information on how many counters may be accumulated in the "kalah" belonging to player A (or player B--the opponent) at a given depth and from a selected field.

A IIA (IIB) message contains information on how many times player A (or player B) can create a threat to the opponent at a depth prescribed by the subject and from an initially selected field.

A IIIA (IIIB) message contains data on the concrete number of moves into a "kalah" possible at the given depth for player A--the subject--or player B--the opponent, if the subject makes the first move from some particular field.

A IVA (IVB) message is brief. It is a "yes" or "no" reply to the subject's question as to whether or not it is possible to threaten the opponent or move into the "kalah" in the given game situation and at a particular depth.

Let us go on to a description of other forms of messages representing substructures of "dialogue" interaction. There are messages which participate in organization of the "dialogue" itself between man and computer, which determine its rhythmical structure and which document individual moments of interaction. There are auxiliary messages (the second form) which, in addition to performing the listed functions, help the individual ask the right questions of the computer, since they contain information indicating the presence or absence of mistakes in a previous question the individual had submitted to the computer. Messages of the third form are a special set of computer sentences which encourage the subject to maintain a positive attitude toward interaction with the computer and toward his participation in the process of joint problem solving. Such messages have nothing to do with the problem solving process directly; they have an indirect influence on the effectiveness of interaction, and they sustain the activity of the individual using the computer in his work. Their presence in the "dialogue" structure makes the work of nonprofessional computer users easier by reducing the monotony of the technical procedures. The computer prints out various sorts of phrases to reward particular actions by the subject. To a certain degree, such messages imitate dialogue between people.

The structure of the dialogue programs was developed in such a way that their form could be varied: Transitions are possible from complete, step-by-step listing of the computer's possibilities (in which case only one basic message is received in response to each successive interrogation of the computer) to a brief, abbreviated form in which the subject may receive several messages simultaneously in response to a single inquiry. This structure permits organization of various ways by which the subject can check out the content of the basic messages. The programs written in support of our methods provided for such checking of computer operations by the subject. Whenever he desired, the subject could verify the basic message either by examining a special print-out of the computer's decision tree variants, or by receiving a supplementary message describing how the computer arrived at the content of the first basic message.

In the complete form of "dialogue," a detailed list of all basic messages and instructions to the subject indicating how to compose an inquiry is automatically printed out by a typewriter connected directly to the computer. As an example, in the first variant of the programs the beginning of a "dialogue" would appear as follows:

Computer: Proceed.

Man: No.

Computer: The computer will now help you in your game. For this, you will need to communicate your wishes to it. For example you may wish to know the rules of the game, to receive advice on the next move, or learn about some tactics of the game which would help you to win. What do you wish to receive: advice, rules, tactics? Indicate in your response: advice, rules, tactics.

Man: Advice.

Computer: Advice may be given:

1) In relation to a concrete position,
2) in relation to a game situation,
3) in relation to certain tactics of the game.

Indicate in your response: position, situation, tactics.

In the brief form, the subject's inquiries consisted of the codes of the basic messages, the number of the field under analysis and a statement of the depth of analysis of the game situation.

In the brief form of the "dialogue" the typewriter printed out the problem in symbols, the content of the subject's inquiry related to a particular basic message, and the computer responses. An example of the brief form of "dialogue" for the second variant of the programs and problem 1 would be:

Computer: Brief form?

Man: Yes.

Computer: Advice?

Man: The opponent's threat.

Computer: Report the field you are analyzing.

Man: 5.

Computer: To what depth do you wish to have advice?

Man: 2

Computer: In this situation your fields are not threatened by the opponent.

Instructions, Problems and the Plan of the Experiments

Experiments were conducted to reach the main objectives of the research: A plan for preparing subjects for work with this method was drawn up, and the requirements and conditions of the experiments were formulated. The method was used in experimental studies differing in the goals and the concrete problems to be solved by the subjects, the instructions and the variants of the dialogue programs (Table 1).

Because the possibilities for using different types of basic messages and forms of control over the computer's actions were diverse, experiments dealing with different aspects of joint problem solution by man and computer could be performed. The expermental research was conducted in two stages.

In the first stage one of the participants (the principal participant) was able to ask the computer for "advice" during the game, while the other subject, who served as the principal player's opponent, did not have this possibility. The activities of the principal subject were analyzed in the study. The activities of the other subject were not considered in this research.

The principal subject was given the following instructions.

"You will be playing with an opponent who is in another room. The computer will help you during the game. After the opponent makes each move, interrogate the computer for a message. However, you may make the final choice of move yourself. The computer does not obligate you to strictly follow the recommendations it provides.

"Your opponent will play without computer assistance. Take your time, the computer will wait for your replies patiently during the "dialogue."

In some cases, at the request of the subject, he was permitted to make one move without interrogating the computer (a move into the "kalah"). This move was unique in that it permitted the subject to take one more move, though for this second move the subject had to interrogate the computer. After this, it became the opponent's move. As was stated in the instructions, computer interrogation time was not regulated.

In the main (second) stage of the research the instructions, the problem and the list of the computer's possibilities were given on separate cards. The instructions read as follows:

"Your goal is to find the best move. You may interrogate the computer for advice whenever you wish. You have been furnished with a list of advisory statements. Your fields are in the top row. During the play, you may accept any item of advice any number of times in relation to any of your fields, to depth X."

Table 1. Distribution of Experimental Series

	Series	Program Variants I	Program Variants II	Type Activity: Game	Type Activity: Problem Solution	Depth of Game Situation's Analysis	Experimental Conditions (Main Messages Used): Complete Set	Experimental Conditions (Main Messages Used): Limited Number	No. of Subjects	No. of Problems Solved	Notes
	Preliminary	+	-	+	-	5	+	-	16	-	Use of two types of interaction--"correct" and "false" advice
	1	-	+	-	5,6	1-5	+	-	10	20	Unrestricted
	2	-	-	-	1,3,5,6	1-5	+	-	8	9	Modification of series 1--concrete instructions given
	3	-	+	-	1	1-5	-	+	9	9	Only one pair of messages from the entire set was given
	4	-	+	-	2,3,4,5	8	+	+	10	17	"
	5	+	-	-	1-6	5	-	+	16	58	Inquiry following statement of player's move
Principal	6	+	-	-	1-6	5	-	+	4	8	Inquiry before problem solution
	7	+	-	-	1-6	5	-	+	10	24	Order of inquiry not regulated
	8	+	-	-	1-6	5	-	+	5	15	Unrestricted inquiry in relation to all fields
	9	+	-	-	1-6	5	-	+	5	13	Only one inquiry per message
	10	-	+	-	2,6	3-6	+	+	9	16	No. of messages used was varied
	11	-	+	-	1-6	5-7	+	-	9	9	Subject used investigative procedures

These instructions were given for investigation of unrestricted interaction (series 1, 2,10,11). In the other series we used a modification of these instructions indicating the specific messages which the subject could use (Table 1). The experimental material in the principal series consisted of six problems selected in such a fashion that to the extent possible, different functional features of a game could be represented in the initial situation. The situation could be neutral, with the player and opponent enjoying an equal advantage, or the player (the subject) could be faced by a threat (a trap). In all problems, the best move was not made clearly evident to the subject; on the contrary the opponent was more than likely to have the advantage, since his situation contained the preconditions for setting up fast accumulation of counters in his "kalah."

Time was not limited in the preliminary series and in the subsequent, principal series--that is, the subject could ponder over the problem (or the game match), over his choice of the main message and so on for as long as he liked (within the limits of the maximum duration of an interaction session). The maximum duration of a session was 2 hours.

To make the game more interesting the conditions of interaction were changed in certain cases during the preliminary series. The subject was not warned of such changes. Two types of interaction were foreseen:

the "correct" message,

"false" advice.

In the first type the objective content of the computer messages offered to the subjects corresponded to the real properties of the game situation. In the second type the objective content of the computer message was inconsistent with the game situation. An example of a "false" message would be a recommendation to make a move from a field containing no counters.

The subject and his opponent were prepared for the game in special training sessions consisting of two or three game matches or two or three problems (in the principal series). In these sessions the subjects acquainted themselves with the rules of the game, they were shown various tactics, and the advantages of particular strategic goals were explained with examples of real game situations.

Subjects that were to use the computer in subsequent experiments were taught the technique of interrogating the computer with a typewriter console, and to compose and feed inquiries into the computer. In supplementary sessions they acquainted themselves with the set-up of the room in which the experiment was to be conducted. The experimenter demonstrated the possibilities of "dialogue" programs, and he showed how a decision tree is built, how evaluations are calculated and how the computer determines the best move. In the preliminary series of experiments the subjects worked with a real "kalah" game board and a set of counters (Figure 1). The positions and moves of the subjects and the responses of the opponent were transmitted back and forth by telephone. The subject fed data on the game situations into the computer in symbolic form:

*14 8,2,11,1,5, 0--the first line of the computer message;
* 5,3,0,3,0,4, 16--the second line of the computer message for the game situation shown in Figure 2.

The time between preliminary training and experimentation varied from several hours to several days, but the research results showed that this time did not have a significant influence on the play of the game.

After the subject was given his instructions and problems, the subject was allowed to interrogate the computer only after analyzing the problems he was given. In the principal series of experiments the experimenter set the moment when the subject could interrogate the computer, for example only before the subject began solving the problem or after he decided upon and committed himself to a particular move (series 5,6; Table 1). In this stage of the research the conditions of using the messages were varied extensively from unrestricted (series 1,2,10,11) to restricted; in the latter case the subject was allowed to use only one type of messages (or one type of message pairs in the second variant of the programs: series 3,5,6,7,8,9). In certain series the number of times the subject could interrogate the computer for a message was varied (series 9, Table 1). This method also permitted us to vary the complexity of the problems by increasing the depth to which the subject had to determine the best move. Thus the instructions required the subject to find a solution one or two moves ahead, and so on.

Use of a modern computer facilitates automation of the experimental process: The parameters can be recorded, subjected to initial processing and displayed automatically.

By maintaining a psychological approach to writing the programs of man-computer interaction, which was organized in the method as a rhythmical structure, we were able to achieve registration of individual activity parameters with respect to time. The principal temporal characteristics of problem solving jointly with the computer were recorded on special computer information carriers (a wide-carriage alphanumeric printer was used). These characteristics were related to time (reckoned from the moment the subject received a computer message to the moment he fed his inquiry into the computer). This permitted us to assess the time taken by the subject to think out the main message and the conditions of the problem (the chosen field and depth), and to analyze the message itself. Temporal characteristics are shown in Figure 3. Information on the experiment and on the subject, the quantity and type of messages used in the experiment, the number of wrong actions and the total interaction time were also printed out on the same information carriers. In certain cases when the subject used certain forms of information verification, a step-by-step print-out of the game tree, or a fragment of the tree to the depth prescribed by the subject, was immediately furnished. Because the entire "dialogue" between man and computer was printed out with a typewriter which also served as the means of operational communication with the computer, the entire interaction dynamics were recorded automatically.

Automatic recording was combined with traditional methods of documenting activity:

"reasoning aloud"--verbalization of the components of activity;

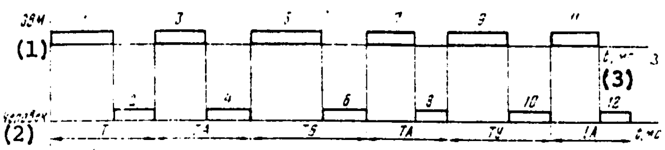


Figure 3. Diagram of Temporal Relationships: *1*--initial "dialogue" conditions; *2*--selection of a type of computer message; *3*--selection of a field by the computer; *4*--selection of a field by the subject; *5*--a message concerning the opponent's move; *6*--selection of a field by the opponent; *7*--determination of the possible depths of analysis; *8*--selection of a concrete depth of analysis; *9*--receipt of a computer message and request for further explanation; *10*--explanation of computer message, receipt of additional information; *11*--continuation of the solution process, or transition to the next problem; *12*--resumption of the "dialogue" cycle

Key:
1. Computer
2. Man
3. Msec

an interaction recording sheet--permits isolation of the stages of investigative activity, its dynamics depending on the types of messages involved, and the dynamics of game situations depending on the current move;

the subject's retrospective report, given after the experiment and permitting the experimenter to reveal the subject's attitude toward different messages, toward the "dialogue," and toward his own activity;

replies to the experimenter's questions;

the solution results--that is, agreement or disagreement between the move selected by the subject and the computer solution, and use or nonuse of computer messages in move selection.

§2. Psychological Factors Governing Joint Problem Solution by Man and Computer

Analysis of theoretical works and of the results of experimental research, and the experience of operating real man-computer systems permit suggestion of the hypothesis that interaction between man and computer in solution of intellectual problems is a part of the general structure of thinking activity, and it influences its effectiveness. The effectiveness of interaction between man and computer during problem solution depends on the psychological principles of this interaction, inasmuch as the computer serves as a tool of the individual's thinking.

The Structure of Joint Problem Solution by Man and Computer

The results of research using program variant I permit the conclusion that analysis of the game situation, the search for the best move and the nature of requests for the basic messages were the same for all subjects. The one difference lay in the dynamics of interaction, which had an effect on arisal of several forms of interaction in the preliminary series and on the diversity of the ways these messages were used in the thinking process itself.

The experiments showed that joint solution is typified by two forms of investigative activity. The first is associated with problem solution, with analysis of the situation and with formulation of intermediate and end goals.

The second form concerns interaction between man and computer. This form of investigative activity has the objectives of finding those types of messages which would correspond to the subject's goals to the greatest degree, of composing inquiries and receiving responses to them from the computer, and of evaluating the adequacy of a received message and the subjective assessment of the end goal formulated by the subject. These two forms of investigative activity are combined together during joint solution to form a structure similar to that seen in the joint activity of people solving a problem.

Thus subject Yu. M. analyzes the game situation from the standpoint of the possibility or impossibility of causing the opponent to suffer a loss and evading a threat from the opponent's side.

> "Field 6 has nothing to offer.... Field 1--no chance for an attack.... Now the threats. The opponent has 13 counters in field 1; I have to come to the rescue of my field 6.... But can I ask the computer for two different items of advice at the same time?" (When told that he could request only one item of advice, the subject continued with the following). "This means that I will have to move from 2 to my 'kalah' and the move in such a way as to 'kill' the opponent's possibilities.... That means I need to get an evaluation from the computer. We have clarified the tactics, and there is nothing obviously threatening about the situation" (the subject checks out advice in classes I, II and III).

What the subject is actually doing is using the computer message as a means for checking and comparing his own goals with those basic messages from the computer which provide full information on how to proceed in the given game situation. In certain cases subjects use computer evaluations to verify and compare them with their own evaluations of moves already made:

> Subject A. M.: "I don't want to use the advice on this move because I can't make out exactly what is happening here; if I've made a mistake, I see it from the evaluations."

In the experiments, subjects formed special goals aimed at revealing the potentials of the computer in terms of solving particular problems, rather than simply in terms of the uncertain situations typical of the training series, in which the experimenter demonstrates the potentials of the programs:

> Subject Ye. P.: "It would be interesting to find out what the computer could do for me; therefore I will ask for all messages in succession."

Later on, if a subject had participated more than once in the experiment, the number of requests for messages of different classes decreased. Class I messages recommending the best move are used most often.

Thus, replying to a question from the experimenter concerning what advice was the best, subject L. M. answered:

> "Which items of advice were most valuable to me? Advice item GP3 (class I); the rest were less so, and I could not understand how GP5 was different from GP3. Advice on tactics (class III) is advice on rules of the game, but they are clear enough as it is. Advice on the situation (class I) didn't help me in any way...."

However, different subjects find the meaningfulness of messages to be different.

To subject A. Kh., class III messages on tactics were the most meaningful, and this subject's entire search for the best move was based on the use of messages in this class:

> "Now let's look at tactics. I'm not ready for tactic 1 yet, or tactic 2 because I don't have any counters.... Tactic 3.... It's a possibility. I want to employ tactic 3, which would mean I would still have another move. What would happen if I moved from field 5.... Let's say I start with 5.... (He reads the tactics).... Aha!.... I want to see if I can collect 13 counters in field 2. How? If I begin with 4, I would be able to place one (counter) there; if I begin with 6, doesn't work. Three is better. What if I ask for an evaluation of my position (for a class I message)? Yes, I want GP3 advice. (He continues after the computer's reply). No, the computer's suggested move won't get me to field 2.... Let me try it myself.... I'll try to make several moves on my own, and then I'll ask the computer about the situation if I get in too deep. In general, it's easier to work with the computer. It's like a crib sheet."

Use of "false" advice in the experiments showed that subjects exhibit varying degrees of independence in their interaction with the computer. Not only external factors but also the individual's *a priori* assessments of the computer's possibilities have a significant influence on their independence. External factors may prevent joint solution, for example in cases of technical or other systemic failures, or when "false" advice is given. It turned out that external factors play a more-secondary role than do the *a priori* assessments made by the subjects of the computer's possibilities and of its role in joint problem solving.

In the experiments, "false" advice was given to only three subjects (Ye. P., O. M. and A. Kh.), with the most being given to subject Ye. P. (for four moves in succession), who assessed the computer's possibilities realistically prior to the experiment. Despite such frequent and continuous provision of false information by the computer, this subject did not break off his interaction with the computer. Moreover he even tried to receive information from the computer about the possible consequences of the opponent's actions, for which purpose he utilized the functional features of the GP3 message. Because such a message could provide predictions only in relation to the principal player, he switched his positions with the opponent's positions.

Subject O. M. interacted in an entirely different way; she considerably exaggerated the possibilities of the computer. She offered the following evaluation of her future joint work in problem solving:

> "It's amazing how much this computer can do; it probably has a very complex program. It's a good thing that it can be my adviser!"

But following just one "false" item of advice the interaction ceased immediately, and the subject refused to ask the computer again for a new message.

> "Well now, let me ask the computer, it's fun with the computer. (She asks for a GP3 message and receives false information). Well, I have to move somewhere.... But why did the computer suggest a bad move? I can't really pass up a move, can I?"

Four types of manifestations of activity were observed in the research.

1. Cessation of interaction in response to external intereference (program failures, mistakes made by subjects when composing the game situation, cases of "false" advice) without attempts at its subsequent resumption. Subjects analyzed and selected the next move independently, without the computer's help (subjects O. M. and L. M.).

2. Interaction between the subject and the computer characterized by two forms of investigative activity: to verify the game situation and the basic computer messages (subjects L. M., A. K., M. K., D. M.).

3. Transformation of the structure of interaction in such a way as to change the structure of interrogation and simultaneously receive two messages together or to organize faster "dialogue." Before receiving the opponent's response, the subject types in messages (auxiliary messages) containing no information having a direct bearing on the problem at hand (subject A. Kh.):

> "While he's thinking and making his move, I'll find out what GP3 is."

4. Transformation of computer messages by means other than those foreseen in the instructions. This happened when a subject tried to determine what the computer assessment of the opponent's future moves were (subject Ye. P.--in a situation of recurrent "false" advice; subject Yu. M.--in a situation of recurrent, lengthy inconsistency between his evaluations of the moves he selected and the evaluations received from the computer in a GP3 message).

The entire process of joint solution was accompanied by statements--evaluations of a special type reflecting the subject's attitude toward the selected message, toward its result, toward interaction, toward the problem and toward his own participation in joint solution. The results of the experiments showed that the evaluations of the subjects had a significant influence on the solution process and on its effectiveness from the standpoint of making maximum use of information contained in a basic message. Four types of evaluations were revealed.

1. Evaluations of the content of computer messages.

> Subject L. M. evaluates the content of a GP3 message: "GP3 advice provides evaluations.... Makes it clear right away.... Two goals possible; the best move is.... I can see which positions (fields) have the highest evaluations, and I can compare them with my own. GP3 messages are useful, they provide a great deal of information right away."

2. Subjects' evaluations of their participation in joint problem solution. A tendency for the subject to do the maximum amount of work, as manifested in analysis and comparison of the results of the subject's own goals with information received from the computer, was most typical of most of the subjects.

Subject Yu. M. evaluated his participation in joint solution as follows:

> "I enjoyed working with the computer, but were I to follow the computer's advice to the letter (he was referring to a GP3 message stating a specific recommendation for a move), there would be no food for thought left. Using a GP3 message, I could evaluate and compare my move with the computer's move and analyze any discrepancy."

> Subject L. M.: "When I received a GP3 message, I began to feel that the computer was trying to help me.... I was very happy to learn that my evaluation agreed with the computer's."

3. Evaluations of the temporal characteristics of different substructures in the dialogue programs. Thus the subjects were not irritated by the amount of time spent by the computer to calculate the game tree.

> Subject L. M.: "The time the computer is taking is not out of the ordinary; I'm still thinking about my move."

> Subject A. Kh.: "While the computer's computing, I'm thinking about the situation."

> Subject Yu. M.: "Does the computer think as long as a man would? Fifty seconds? Is that all?"

However, almost all subjects noted, as a negative factor of interaction, the long time it took to receive responses to auxiliary messages serving to organize and resume "dialogue," despite the fact that the real time spent on typing messages such as "Play" and "Tell me which item of advice you have selected" was much shorter than the computer solution time.

> Subject A. Kh.: "It types awful slowly." The subject keeps repeating: "Let's get on with the game."

4. Subjects' evaluations of the experimental situation. In general, the attitude toward the experiment was one of interest. Recurrent participation by some subjects is evidence of this interest. Five out of eight subjects participated in the experiments more than once. They expressed a wish to continue the experiment on.

In the course of interaction during the experiments, evaluations of the content of main messages (type 1 evaluations) underwent change. Various forms of the use of information contained in basic messages were observed, from their total rejection to acceptance of the basic message and its inclusion into the solution structure without changes. Of 78 game situations, 15 were characterized by total violation of the structure of joint solution, 15 were characterized by partial violation, subjects made 20 moves under the influence of information contained in the messages, and in 28 moves they used the computer's information as it stood, without changes. Thus we observed the following.

a) Total violation of the psychological structure of joint solution, the subject's refusal to interrogate the computer for messages.

> Subject A. K.: "First I will try it myself, and then I will see what the computer has to say."

b) Partial violation of the joint solution process, manifested as ignoring a message's information following interrogation of the computer.

> Subject Yu. M.: "I could prepare for an attack, clear out 1 or 5; I should leave 6 alone for the moment.... I'll ask for GPS advice.... (After receiving the information:) Interesting! The computer gives the highest evaluation to 4. But what about 5--a zero evaluation?!. Is it really a totally useless move? I don't know, I think I'll move from 5 anyway."

c) Partial acceptance of a computer message: The subject does not formally accept the information (for example a recommendation for the best move), but it does have an influence, causing the subject to re-analyze the game situation and reformulate his end goal. The subject selects a move from a field which he had not considered in his initial analysis.

d) Acceptance of the computer message and its inclusion into the structure of the solution without change. This form arose when the game situation would not allow the subject to achieve the strategic goal he selected, or when the result hoped for by the subject was consistent with the computer data.

Subject A. Kh.: "Now why did the computer say that? Let me think this out myself. What sort of tactic do we have available? (He inspects the class III messages). Oh, now I understand--I need to fill up my opponent's empty position."

Psychological Factors of Effective Interaction

Experiments conducted in the preliminary stage of the research provided a general psychological description of the activity of subjects solving mental problems in a "dialogue" with a computer. The forms of investigative activity were revealed, and their role and structure in the overall process of joint solution were determined. It was demonstrated that the joint solution process is typified by manifestations of certain types of activity, which played an important role in organization, maintenance and sustainment of interaction between man and computer.

The subject's activity also manifested itself in his system of value judgments concerning various aspects of joint problem solving. These evaluations have a significant influence on the effectiveness of communication with the computer and use of the information it provides. Analyzing the forms of use of computer data, we can conclude that in this stage, for practical purposes the subjects never did achieve true (informal) joint problem solving.

This fact may be explained by the following: first, by the novelty of the situation and the almost complete absence of information on psychological mechanisms influencing "dialogue" interaction, and second, by the orientation of the first variant of the programs toward formal methods and tactics most typical of modern "artificial intelligence" systems. The results and these conclusions permitted us to formulate the hypothesis that goal-forming processes are the most important prerequisites of effective use of computer information. Expansion of the individual's possibilities for posing qualitatively new goals, leading to optimum solutions and the best results, can serve as the effectiveness criterion. To confirm this hypothesis, in the main stage of the research we studied goal formation during joint problem solution by man and computer (series 1-4, 10, 11). In these series the subject's use of the computer as an assistant and an adviser led to qualitative transformation of his thinking. Comparative studies were also performed on the use of the first and second variants of the programs (series 5-9). Series 1-9 were performed in cooperation with T. V. Kornilova.

The results of the preliminary series showed that differences in the ways computer messages were used depended mainly on the structure, composition and content of the basic messages. Moreover the first variant would not permit acquisition of a complete prediction of the possible consequences to the player and the opponent at different depths of the player's analysis of the problem.

An analysis of evaluations made by subjects concerning the form of communication with the computer showed that the "dialogue" form had to be more flexible, that it had to be more adaptable to the dynamics of the thinking process itself. We found that different ways for the subject to verify computer solutions had to be provided.

When computer messages are consistent with the content of the goal forming process (as in the second variant of the program), the subject includes these messages into the problem solving process as is. At such times the subject exhibits subjective satisfaction in joint work with the computer (series 1, 10, 11). In cases where computer messages were inconsistent with the content of goal formation, the attitude expressed toward interaction varied (series 5-9). The subjects not only failed to find what was objectively the best move, but they sometimes even rejected the best move recommended by the computer. Computer advice was accepted in only 38 percent of the cases, being rejected in all others. In series 2-4, sometimes the subjects did not analyze the mental problem independently; they mechanically utilized the computer messages. However, despite the fact that there was almost no preliminary analysis of the problem in these series, the results of the mental activity were much better than in series 5-9, and computer messages were accepted in all cases.

The best results were achieved in series 1, 10, 11. The objectively best move was found in 18 out of 20 problems (series 1) and in 22 out of 25 problems (series 10, 11). The moves found by the subjects were objectively the best according to the computer's criteria. In the remaining cases, the disagreement between the subject's move and the objectively best move (as determined by the computer's criteria) was associated with the fact that during preliminary analysis, this given move had not been verified with the computer's help.

In series 2-4 the best move was found in 73 percent of the cases, and the thinking effectiveness was significantly higher than in series 5-9 (in which a correct solution was found in only 44 percent of the cases). The difference in thinking effectiveness between series 1, 10 and 11 on one hand and 2-4 on the other is associated, first of all, with the greater complexity of the problems solved by subjects in series 2-4 (to a depth of 5-7, as opposed to a depth of 5 in series 1); second of all with the limitations imposed on the types of computer messages employed and on choice of the depth of computer analysis; third, with the absence of additional resources with which the subject could check and verify computer messages he used in the course of his thinking. These additional resources (step-by-step print-out of the computer's actions on special information carriers--alphanumeric printers, and the explanatory information the subject received in regard to his initial message) were added to the method in series 10, 11. As a result thinking effectiveness was increased to 90 percent (as opposed to 73 percent).

In series 3, in which subjects solved a problem using a restricted pair of messages, different means of communication with the computer were observed: sorting through all move variants (six out of ten subjects interrogated the computer for information on all possible fields in the game situation) and selecting information regarding only the specific fields under examination (four subjects). However, despite the fact that this was not the optimum solution, four out of the six subjects gave a positive evaluation to their joint work with the computer.

The qualitative change in goal formation processes which occurred in series 1, 10, 11 and in certain cases in other series using the second variant of the programs was accompanied by gradual transition from analysis at a depth within the means of the subject, without the computer's help, to analysis at a depth of 5-8 using information from the computer. The content itself of the subject's goals changed under the influence of the computer messages as well: Game situations began to be analyzed in conformity with the content of the basic messages.

> Subject I. V.: "O.K., can I ask for a message indicating the number of threats?. Seventy-nine out of 216 game situations? I won't be able to consider 216, and even 79 would be difficult."

As was noted in the research (in series 4), this transition to a greater depth of analysis was not always accompanied by a qualitative positive change in goal formation. In certain series the latter had its limits, or zone. Thus in series 4 at depth 8, computer messages were not always included in the goal forming process.

> Subject M. B.: "At depth 5 the computer was helpful, because I was able to evaluate and weigh, and then compare, while at depth 8 the computer does not provide any information that I could judge as being correct on the spot."

A typical feature of all problems solved by the subject was a need for analyzing several solution variants (from one to six). The search for the best move exhibited its differences when preliminary analysis occurred before or after interrogation of the computer. When the computer was not interrogated the different variants were examined more extensively, while problem solution jointly with the computer tended to reduce the zone of analysis. In series 1 as an example, from one to five fields were checked out with the assistance of the computer in 17 out of 20 cases. In this case the subject analyzed from 3 to 19 items of advice, utilizing messages ranging in number from one pair to the entire set. In two cases selectivity of analysis and move choice had a negative effect on the results.

In the final analysis, a qualitative change in the goal forming process occurred in this stage, allowing the subject to act more productively. In cases where the second variant of the program was employed, most subjects interpreted interaction with the computer as joint problem solving.

> Subject S. M.: "Today the computer really worked liked an adviser, because I was able to check my own moves with its help. (Experimenter: 'You mean as a verification mechanism?'). No! Before (in series 5) I selected the move and the computer told me yes or no, while here it is different: Here it (the computer) could tell me everything about each field.... Before, I thought that it was deceiving me, while here I could not but believe it. All of the calculations were there to see."

Thus utilization of the computer's potentials was fuller than in the first variant of the programs. For variant I, the frequency of referral for messages during analysis of one game situation averaged 2.38, while for variant II it averaged 6.6. Differences were observed in the nature of requests for messages. Out of 107 requests in the first stage of the study, 77.5 percent were associated with class 1 messages, 14 percent were associated with class 2, and only 8.4 were associated with class 3. In series 1-4, 10 and 11 of the principal stage of the experiments, the frequency of requests for messages concerning accumulation of counters was 71.2 percent, while the frequency of requests for the rest of the message pairs was 29 percent in series 1-4 and 45.5 percent in series 10 and 11.

As in the preliminary series, in the principal series joint problem solving was accompanied by a special type of statement--evaluations characterizing different aspects of this process. Evaluations stated during "dialogue" with the computer were identical in nature for almost all subjects. Auxiliary messages, which had the function of organizing the structure of interaction, never received negative evaluations. All subject responded positively (with laughter, with excitement) to special messages. "How well mannered your computer is!"; "I enjoy communing with the computer, it's as if we are really talking"; "Tell me, will the computer understand the word 'please'?".

Thus the following changes in goal forming processes were revealed in the principal stage: 1) modification of goal formation, on the basis of computer messages, in terms of both content and depth of analysis; 2) adjustment of the subject's goals to make them correspond to the wording of the computer messages; 3) violation of goal forming processes under the influence of computer messages. The experiments showed that if subjects are to make effective use of the content of computer messages, they must observe certain conditions. There must be no restrictions in the possibilities for using different types of computer messages, for making arbitrary changes, and for selecting the depth of computer analysis. The rhythm of the "dialogue" must be such that the subject would be able to act jointly with the computer, to analyze the goal forming process and to check the computer information out.

It was revealed in a comparative analysis of stages 1 and 2 of the research that "dialogue" programs have an influence on the individual's activity in general in relation to the entire set of different forms of messages (substructures). Thus depending on the degree to which the content of goal formation is accounted for in a "dialogue" program, we can observe two qualitatively different processes--truly joint solution and formally joint solution. Thus our experiments showed that inclusion or noninclusion of computer data into the problem solving process is a parameter significant to evaluation of the overall effectiveness of man-computer systems.

§3. Psychological Problems in Analyzing the Effectiveness of Man-Computer Systems

The leading specialists in computer planning note that extensive application of computers in human intellectual activity requires development of new programming methods and "dialogue" interaction modes, the quality of which has a direct influence on the effectiveness of man-computer systems (34,59,85,90). Today, the labor-intensiveness of developing the software for such systems is from 400 to 5,000 man-years (49), depending on the complexity of the problems solved together with the computer, and it has a tendency to grow geometrically in comparison with the outlays on the required hardware. Developers often view computers as nothing more than arithmetic units. The recent literature, however, especially the foreign literature, notes: "The interpretation of a computer as an arithmetic machine compels us to distribute our accents in such a way that special attention is devoted to the internal structure of the machine, in detriment to and at the expense of man--the user; in other words users are forced to plan their work in a manner convenient to the machine" ((90), p 14).

Data transmission system specialists believe, on the basis of the experience of many foreign countries, and mainly the USA, that whenever users themselves feed the information into the system or engage in a "dialogue" with the computer, the psychological features of problem solving have the principal influence upon the system's development. "System users may vary. Some know programming techniques while others do not. These differences lead to differences in the structure of the dialogue. In the future, when communication resources of greater diversity will appear, this difference will be amplified" ((90), p 24). The need for simplifying "dialogue" programs and adapting them to the needs of nonprofessional users is now being noted in foreign software planning (59,36).

It should be noted that the literature on engineering psychology which, it would seem, is most closely associated with our subject matter, does not consider the effectiveness of "dialogue" systems in any special way; moreover the more-general characteristics of human activity in man-machine systems cannot be applied directly to evaluations of the effectiveness of "dialogue" systems. As an example researchers attempting to use, as an effectiveness criterion, "the capability of a human operator to solve a problem promptly, accurately, over a given amount of time and with minimum outlays of effort, resources, energy and materials" ((48), p 35) digress from the characteristics of the subject's real creative activity (goal formation, formation of evaluations, the dynamics of the latter and so on). One of the reasons for insufficient development of the effectiveness problem is that researchers have been concentrating on the activity of a human operator rather than a user. The activity of users differs from the activity of operators not only in the content of the problems they solve and the temporal characteristics of the solution process, but also in the structure of the "dialogue," the composition of which is more complex.

Let us look at the way the concept of the effectiveness of computer use is interpreted within the framework of man-computer systems. In the cybernetic approach, interaction effectiveness is considered from the standpoint of the following factors: solution quality, time and cost (103). Authors adhering to this approach believe that these factors are directly associated with certain characteristics of interaction--mutual understanding and psychological preparedness. The concepts "interaction" and "dialogue" may be interpreted differently in application to "dialogue" systems, and these differences have an effect on the analysis and planning methods used with "dialogue" systems, which in turn reflects upon the approaches taken to analyzing the effectiveness with which these systems function.

There are two interpretations of the term "interaction." In the cybernetic, informational aspect "interaction" is defined as "exchange of messages between man and computer in support of the need for successive or parallel performance of actions by man and computer in joint solution of some sort of problem" (110). In the psychological interpretation a user working on mental problems with the assistance of computer messages must interact with the computer "when the user experiences the need for referring to the computer; in this case the nature of interaction must approach the rhythm of a natural psychological process" ((105), p 38).

From a psychological point of view man's problem solving activity involving the use or nonuse of messages received from a computer can be called interaction. This activity depends on the individual's objective attitude toward the computer messages, the goals formed by the subject and the choice of the means for their attainment. Activity may change under the influence of computer messages. In particular under favorable conditions the creative components of activity go into action. As our experiments showed, the computer influences man not only at the moment of inquiry and receipt of a message from the computer. The individual's conception of the computer's potentials and of the particulars of the program has a significant influence on his preparedness to use (or not to use) computer messages, and it influences the effectiveness of their interaction. Some studies imply that the individual features of the user have a significant influence on the productivity of interaction (59,82).

The expression "joint problem solving by man and computer" is used in descriptions of interaction between man and computer to mean purely external form of organization of interaction. From the psychological point of view not all situations of exchange of messages between man and computer can qualify as joint problem solving. It would hardly be justified to say that joint problem solving is occurring when subjects reject the computer messages. Joint problem solving refers only to interaction organized in such a way that computer messages are accepted by the subject and included in the structure of his activity, particularly in the goal forming process. It is only under these conditions that the subject forms a positive attitude toward the computer messages and toward the computer in general. Failure to consider these factors may reduce the effectiveness of interaction.

The following characteristics are used to describe the concept "interaction": a) mutual understanding between man and computer; b) psychological preparedness to engage in interaction; c) accessibility of the computer to the individual; d) swiftness of computer responses; d) convenience of communication (103). Each of these characteristics may be interpreted in different ways.

It is sometimes said that a user is psychologically prepared to engage in interaction when he has a ready-made algorithm with which to solve the entire problem or some part of it. This is a very important parameter of activity, but as our experiments showed, preparedness for interaction depends mainly on the individual's attitude toward the computer, which can be characterized by his *a priori* evaluations of the computer's potentials and the evaluations formed during interaction itself. It may assume diametrically opposed forms--from total refusal to interact with the computer to real joint problem solving.

From a psychological point of view mutual understanding is only a metaphor, since the psychological processes of human understanding include not only formal processing of information symbols but also analysis of the meaning of a message, as well as the emotional reactions accompanying such analysis, ones absent from computer "understanding." If we stipulate that mutual understanding between man and computer must be a decisive prerequisite of the effectiveness of "dialogue" systems, it would clearly be unattainable. And yet it is sometimes asserted that the principle of mutual understanding is one of the basic factors of effective interaction. It is believed that mutual understanding must "reflect a knowledge of the system of symbolic languages used for information exchange, and the presence of at least a partially coinciding idea about the subject of communication" ((37), p 9).

In this context establishment of mutual understanding implies only man's study of the potentials a computer has for helping solve a certain problem. Correct formulation of a message to the computer by the individual is said to be the principal result in this case. This approach is an abstraction from the complex structural composition of the process of man's comprehension of particular messages.

Accessibility of the computer to the individual may be interpreted in different ways. In some cases it depends not only on the temporal characteristics of the computer and the possibilities of the software, but also on the user's attitude toward the computer. From a psychological point of view accessibility of the computer to man may be associated with the factor of man's trust or mistrust of computer data. The principle of unlimited access in "dialogue" mode must be interpreted not only from the purely formal aspect but also from the psychological aspect, since when subjects do not accept computer messages or when they solve problems without using the computer, access is limited.

Computer reaction speed must be evaluated with regard to the differences in significance of different forms of computer messages (basic, auxiliary, special) to the subject, the complexity of the problems being solved and the user's *a priori* evaluations of the expected computer response time. *A priori* evaluations of computer reaction speed do not always correspond to the actual amount of time the computer takes to solve the user's problem; therefore "dialogue" programs must foresee the possibility for maintaining communication between the individual and the computer in cases of disagreement between subjective evaluations and the real time outlays. Data exist indicating that uncertainty felt during anticipation of a response from the computer may disorganize the user's activity.

Convenience of communication should include, in addition to the universally accepted conditions, consideration of the emotional state of the individual, who personifies the computer in the course of interaction, relating to it as to a partner. If dialogue programs are to be universal, they must not only afford the possibility of broad access to different users, but they must also account for the individual features of the person and the activeness of his participation in the use of the computer information.

A "dialogue" between man and computer and its structure may also be characterized from both a technical standpoint and a psychological point of view. In the context of cybernetics, "dialogue" is defined as work of an individual with a computer typified by periodic repetition of a cycle including assignment of a task to the computer, acquisition of a reply and its analysis. The principal characteristics of "dialogue" are said to be its form (a graphic or alphanumeric structure) and its temporal parameters. From the standpoint of information theory and cybernetics, structure includes only the characteristics of the messages exchanged between man and computer; from a psychological point of view the structure of a "dialogue" implies the rhythmical organization of joint problem solving. The size of a computer message may also be interpreted either in purely formal terms (in relation to the number of symbols it contains) or with a consideration for its meaningfulness to the individual, the ease and convenience of composing the message and the possibilities for changing its form during joint problem solving.

An analysis of our research showed that if "dialogue" is to be organized effectively, in such a way that it accounts for the psychological characteristics of the user, the computer messages must be differentiated in terms of the functions they perform in the activity. Some messages are involved with goal formation, modifying it, others regulate the rhythm of communication, and still others support formation of different forms of relationships with the computer. We found that the accuracy with which the time required by an individual to solve mental problems is predicted depends in many ways on how correctly and completely the psychological conditions governing the rhythm of communication are accounted for.

As G. Martin, one of the prominent data transmission system specialists, notes, "dialogue is a more significant factor in the creation of an effective man-machine interface than is the system's response time" ((59), p 73). This assessment of the significance of the structure of joint problem solving has been confirmed by experiments. For example auxiliary computer messages, which perform a supporting role by organizing the overall rhythm of interaction, represent that "dialogue" substructure which is most difficult to adapt to man. Being the most constant and frequently recurrent form of messages, they should ensure convenience and ease of requesting basic computer messages.

As was shown earlier, two types of problems arise in interaction between man and computer--mental and communicative. Consequently the overall result of interaction depends both on the effectiveness with which mental problems are solved and on organization of an optimum rhythm of communication. This rhythm is precisely one of the decisive elements of communicative problems (13,30).

In contrast to the two-cycle interaction typical of the cybernetic approach (103, 110), our experiments revealed five cycles in the rhythm of communication. Joint problem solving consists of a succession of cycles: 1) analysis of the problem conditions; 2) selection of the particular way to include the computer in the search for the solution; 3) determination of the requirements on the organization of "dialogue," selection of the forms in which to display the inputs and outputs, and composition of the computer inquiry; 4) acquisition of a reply from the computer in relation to a concrete phase of solution; 5) comparison of the computer reply with the initial conditions of the problem, and analysis of the computer reply. Cycles 1 and 2 are central to joint problem solving, since during this period the subject forms his goals, determines the zones within which the search for the best solution is to proceed, and selects an adequate means for acquiring data from the computer. Inasmuch as the time of "dialogue" messages influences the cost of the system, optimum organization of the rhythm of communication is an important problem, one still awaiting its researchers. There is no unanimity of opinion in the literature concerning how fast a computer response must be. Some authors (59) say the faster the better, while others make response speed dependent on the nature of the problems: If they are computational problems, the response time must be within seconds, and if they are not computational problems, the response time would be in the minutes.

From the cybernetic approach, "dialogue" would be most effective when the computer's average response time is sufficiently low (from several fractions of a second to several seconds) (110). According to our data the length of the cycles can vary from tenths of a second to several minutes depending on the complexity of the problem and the content of the computer message. In our experiments the maximum time from the moment of acquisition of a message to the subject's response was 8 minutes 25 seconds (cycle 5), the maximum time until interrogation of the computer was 5 minutes 9 seconds (cycle 1), the maximum time for selection of the message type reached 2 minutes 23 seconds (cycle 2), the maximum duration of cycle 3 was 2 minutes 24 seconds, and cycle 4 varied within 1 minute.

The experimental data revealed a certain dependence between the times of different cycles. An analysis of the temporal intervals recorded in the experiments would indicate a direct dependence between the time of anticipation of a computer response and the time of analysis of the initial problem (cycles 1, 4). Various factors have an influence on the time of cycle 3: the volume and complexity of the inputs and outputs, presence of different forms of displaying the computer results and the structure of the "dialogue." Thus the time spent by the subject to decide on the form of data presentation may be longer than the time spent directly to organize "dialogue" (to print out auxiliary messages).

Analyzing interaction in relation to time, computer specialists distinguish different modes of temporal organization, namely immediate, off-line and batch. The immediate mode presupposes "dialogue" interaction between man and computer in which communication between man and computer is never interrupted during the activity. As a rule "dialogue" messages are short, and they are issued by the computer quickly. Off-line interaction takes longer. In this case complex, voluminous texts, graphs and illustrations are used. In the opinion of certain computer specialists this mode is used mainly for creative problems. In batch mode, interaction time from the moment a problem is fed into the computer to the moment the individual receives finished results may be very great. The emphasis in man-computer system planning is now being laid on immediate and batch interaction modes. The off-line mode, which is most in keeping with joint problem solving, has not yet enjoyed adequate attention in development of man-computer systems. There are presently no recommendations available on how to organize its rhythmical structure, the composition of messages and the software.

Development of "dialogue" systems is sometimes based on the two following methodological principles: development of the theory of problem solving by man in a "dialogue" with a computer, and quantitative research on and formalization of the factors of their effective interaction. In addition to quantitative research on effective interaction, we also need to perform qualitative psychological analysis of the general structure of joint problem solving, to include analysis of mental activity and man-computer interaction.

The experiments showed that the effectiveness of interaction depends to a significant extent on how well the qualitative characteristics of goal formation are distinguished and accounted for in the computer programs. Computer messages are perceived by the individual as advice if they reflect possible change in the conditions of the problem at different problem solving depths. When the process by which the computer arrives at solutions is made available for inspection and when additional means for double-checking a selected message are present (a second explanatory message would suffice), the individual can analyze the computer solutions and persuade himself that the computer is working mainly on those problems which had been given to it by the individual. In this way, mistrust toward information received by the individual from the computer is relieved. The structure of the programs must foresee a possibility for utilizing messages not only in the final stage but also right during joint problem solving. The structure of the program must also reflect the dynamics of the goal forming process.

Interaction which is not recognized by the individual to be joint problem solving is less effective. In such cases the individual may refuse to accept computer messages, he may develop a negative attitude toward them, and he may abandon joint problem solving.

One important factor promoting formation of a positive attitude toward the computer is rhythmical organization of interaction, coupled with inclusion of special messages in the program to simulate dialogue between people. The results showed that introduction of such messages promotes stimulation of the user's activity in the work, especially when external interference is present (errors in message composition, system failures and so on). Moreover the messages make the monotonous technical procedures of interaction more interesting.

Let us summarize the results of our analysis of "dialogue" system effectiveness.

1. An analysis of published data would show that at present, the cybernetic approach to the effectiveness problem, which rests on quantitative characteristics, dominates. Emphasis is laid on the immediate interaction mode in development of "dialogue" systems for man-computer interaction. The off-line mode (joint problem solving), which is typically used with complex problems, has not yet enjoyed adequate attention in the development of man-computer systems.

2. The effectiveness of man-computer interaction (acceptance or nonacceptance of a computer message, the nature of its influence on the subject) depends on the content of the computer messages and the extent to which they participate in problem analysis.

3. The structure of "dialogue" programs must include three types of substructures, having various influence on overall effectiveness and differing in functions and meaning.

4. The overall structure of communication must include not only immediate interaction but also solution of mental problems.

5. The main factor governing the effectiveness of interaction is the content of the basic computer messages, composed with a consideration for the goal forming mechanisms employed by the subject during solution of a mental problem.

6. The effectiveness of the thinking of an individual using computer messages depends not only on the external form of these messages but also on the subject's internal attitude toward them and toward the entire interaction situation. It is only when these effectiveness criteria are met that true joint problem solving exists. On the other hand man-computer interaction that is ineffective from the psychological point of view is typified by violations of the goal forming processes, mechanical utilization of computer messages and rejection of these messages. In this case we are dealing with the "appearance" of joint problem solving.

7. Computer messages used to organize the "dialogue" must be adapted to the individual features of the user.

8. Psychological research on goal forming processes, performed in the laboratory with the methods proposed here, can reveal new heuristics to be used in creation of the decision tree. By accounting for them in problem solving programs, we can significantly reduce computer time.

USING A COMPUTER TO CONTROL GOAL FORMING PROCESSES

O. K. Tikhomirov, Yu. D. Babayeva

The central objective of this study was to analyze the possibilities of using computers to control human intellectual activity on the basis of its psychological structure. We were especially interested in using computers to control those intellectual processes which cannot be delegated to the computer at the present stage of technological development. Goal formation, which is now being studied intensively (76), was chosen as such a process. Preliminary analysis (12) showed that goal forming processes cannot be fully described by the existing methods of formal description. Consequently we encounter the important problem of studying the ways and methods of controlling unformalized processes, since formalized ones can be delegated completely to the computer.

A laboratory experiment was performed to study the process by which a subject words the possible goals of an object of analysis suggested by the experimenter. As we know, there are different forms of goal formation (91). We studied one of them in our experiment--production of possible (conditional) goals. Some authors believe examination of the field of possible goals to be an important component of creative capabilities (146). But at the same time these processes have been left almost completely unstudied by the psychology of creativity (148).

The authors of "idea generation" methods such as "brainstorming" (144), "synectics" (125), "morphological analysis" (156) and so on have come closest to solving the problem of controlling the production of possible goals. However, it is difficult to adapt these methods, which contain numerous unformalized components, to a computer (70,100).

In order to describe some of these difficulties, let us analyze one of the traditional directions of computer use in creative activity, one which is perhaps encountered most frequently today in studies of the possibility of controlling "idea generation" by a computer. In this approach, the computer is used as an auxiliary device in the production and analysis of a certain field of possibilities prescribed by the given algorithm. The computer synthesizes all possible variants of ideas (or their specific rudiments) on the basis of the individual's overall plan and a certain list of elements prescribed by him. A certain set of these elements is fed into the computer memory in coded form. The computer subsequently synthesizes solution variants on the basis of a special combinatory algorithm which, by processing the prescribed elements according to certain rules, prescribes the field of possible combinations.

Justifying the possibility for using a computer in this way in artistic and scientific creativity, A. Mol' points out that in all problematic situations, the field of possibilities is extremely vast as a rule. "A person selecting a certain path in this field may pass by much more attractive variants without even suspecting their existence. Only a computer that systematically applies all rules of combinatorial analysis to all prescribed elements is capable of examining and exhausting the entire field of possibilities" ((61), pp 91-92). In general, this suggestion is quite logical. However, researchers attempting to implement it have immediately encountered a number of fundamental difficulties associated both with the process itself of revealing the elements and the rules and with creation of special "filter programs." Such programs are needed for the following reasons. Selectivity, which restricts the boundaries of the field of possibilities analyzed by the subject, is not only a "nuisance" factor (144) but also one necessary to human thinking. In this case variants are far from always evaluated and selected on the basis of formalized rules that may be embodied within a "filter program." If deprived of such evaluation functions so specific to human thinking, a computer may synthesize such a large quantity of variants that the individual would have to exert an extremely large amount of effort to choose the best. Moreover it is not always possible to reveal the optimum set of rules to be included in combinatorial algorithms, and therefore many variants synthesized by the computer may end up being generally meaningless. Thus the need arises for specially organized "dialogue" interaction between man and computer.

We considered the following to be among the general shortcomings inherent to the presently available methods of using computers to control "idea generation."

1. For practical purposes most methods are not based on psychological information. It should be considered that among their creators (engineers, inventors), there are a few professional psychologists. Psychologists, meanwhile, far from always devote sufficient attention to analyzing these methods, which in our point of view is a significant hindrance to further development of this promising direction.

2. As a rule the motivational and emotional components of activity are not accounted for in attempts at computer realizations of "idea generation" methods. Moreover the opinion exists that many effective ways of influencing man's emotional and motivational sphere, presently being used successfully in a number of known methods, cannot be used today in automated systems inasmuch as they cannot be stated in algorithmic terms.

In our research, goal formation was controlled with a computer using a specially developed "dialogue" mode. The dialogue mode was created on the basis of a preliminary psychological analysis of controlled intellectual activity, and it accounted for the motivational and emotional components of activity. Although we do agree that it is impossible to formalize a large number of psychological factors, we do not share the point of view that it is impossible to make real use of these factors in automated systems.

The effectiveness of modern "dialogue" systems may be raised significantly namely by making broad use of the techniques and methods of controlling unformalized processes.

We can distinguish at least three classes of goals produced by a subject participating in a "dialogue" with a computer.

1. The goals of analyzing an object provided by the experimenter (possible goals). We will abbreviate them as P-goals. Their sum total characterizes the field of possibilities which the subject is able to reveal in the experiment.

2. Goals associated with the subject's direct communication with the experimenter, abbreviated E-goals.

3. Goals arising in the course of computer-mediated communication with the experimenter or other subjects, which we will call C-goals.

The experimental research was conducted with the purpose of analyzing P-goals. The other classes of goals were studied only in their relationship to P-goals.

The Grounds of the Experimental Method

Developing the experimental method, we relied on data from former research (11,12) and on known methods such as Guilford's method of studying "sensitivity to problems" (127), Zwicky's "morphological analysis" (156) and Bush's "chain of ideas and associations" (24). We made use of all these methods for the following reasons.

The extremely few psychological studies of production of possible goals are dominated by experiments involving the use of tests to determine "sensitivity to problems." Relying on these concrete data, we can judge with better grounds the nature of changes made by including a computer in the goal formation process.

In Guilford's opinion "sensitivity to problems" may manifest itself in the form of recognition of the need for certain changes in the situation at hand, or of recognition of defects and shortcomings in things as they are. This "sensitivity" is an important component of creative capabilities; it permits the individual to quickly recognize things that are strange, unusual and contradictory in problematic situations. Recognition of such inconsistencies is, in particular, the source of the goals of actions aimed at resolving them. Guilford developed his "sensitivity to problems" tests on the basis of the assumption that in an experimental situation, a concrete area of problem production may be assigned in the form of certain objects or situations. In this case the more commonplace the situation or object is, the more "creative potential" is required of the subject to reveal "defects, needs and shortcomings" (127).

We made use of the methods suggested by Zwicky and Bush because they are among those few methods of controlling "idea generation" which are best suited to computer use. Both of these methods are based on the use of certain combinatory algorithms. The "rudiments" for P-goals are synthesized using either the rules of complete sorting of all possible combinations of the initially selected significant factors typifying the object under analysis (156), or rules that lead to different combinations of elements in the "chain" of synonyms for the object under analysis and elements of the "chain of associations" (24). This approach, in the opinion of the authors of these methods, permits us to significantly expand the boundaries of the field of possible goals and to reveal new, original directions in research on various technical objects.

The basic premises of our experimental method differ significantly from those described above.

1. As in Guilford's "Instrumental Test"--part of a battery of "sensitivity to problems" tests, the problematic situation prescribing the area of production of P-goals was represented by well known household objects. In distinction from this test, however, we did not impose rigid limitations on the number of goal variants revealed; on the contrary we asked the subject to formulate as many possible goals of analyzing the given object. The specific instruction to seek "defects and shortcomings" was excluded as well. From our point of view this made it possible to judge the features of the field of possibilities revealed by the subject with better grounds.

2. The choice of elements to be fed into the computer memory and to be used in the combinatorial algorithm was based on data from a special preliminary series of experiments. The data showed that these elements may be only the properties of the object of analysis (as is suggested in Zwicky's and Bush's methods) but also concrete procedures permitting the subject to transform property statements into statements of possible goals. "Procedure" is an arbitrary label applied to a certain verbal construct with an omitted phrase, such as "improve ... (property a_i)." If we insert a certain property of the object into this gap, we may arrive at a statement for one of the possible goals of the object's analysis. The concrete procedures the subjects used to produce their statements of P-goals were revealed on the basis of an analysis of data sheets from the preliminary series of experiments.

3. The computer algorithms we developed also differed significantly from those described above. In arriving at computer synthesis of the "rudiments" for P-goals, we rejected the rules of complete sorting of all possible combinations of revealed elements. Instead, we applied special rules accounting for certain differences in the probability that the revealed properties and procedures would appear in the real activity of the subjects. For this purpose we loaded the computer memory not only with statements describing properties and procedures but also data indicating the frequency with which they appear, obtained from an analysis of the results of the preliminary series of experiments.

We developed the methods of this series on the basis of the hypothesis that certain relationships exist between the processes by which statements of possible goals of an object's analysis are produced and the revealed properties of the object. Selectivity typical of human thinking and shrinkage of the field of possibilities analyzed by the subject may manifest themselves both as a certain amount of selectivity in the choice of the procedures, properties and their combinations and as selectivity in application of the procedures to certain properties and their combinations. By obtaining statistically valid data on these features of the goal forming process, we can not only generate nontraditional "rudiments" for P-goals but also develop special subprograms by which to obtain computer statements and possible goals typical of another degree of selectivity specified by the experimenter. This approach opens up interesting prospects for studying goal formation by an individual participating in a "dialogue" with a partner whose selectivity in production of statements of possible goals is structured on the basis of other principles.

Four "dialogue" modes were developed on this basis: "original property," "property," "combination of properties" and "problem." These modes are characterized by the use of randomly generated properties of the object (having different probabilities of appearance), random combinations of these properties and subprograms producing computer statements of P-goals. The subjects could not only freely choose among these modes of interaction with the computer, but also change from one mode to another during their work.

4. Our assessment of the effectiveness of these "dialogue" modes was inseparably tied in with comparative analysis of the productivity of subjects working in traditional conditions (without a computer) and in "dialgue" interaction with a computer. We had to determine whether or not use of these modes causes significant expansion of the boundaries of the field of possibilities analyzed by the subject and reveals more-attractive variants of the possible goals. In this analysis, expert methods were used to evaluate the quality of P-goal statements produced by the subjects.

Studying the possibilities of controlling human intellectual activity through special influences upon man's emotions and motivations is, from our point of view, a new direction in research on various forms of use of computers in this activity.

The productivity of human activity is known to be significantly influenced by emotional and motivational factors. However, because these factors do not yield to formal description today, their use in "dialogue" interaction between man and computer requires development of special methods. In this connection we suggested the following basic hypotheses: a) that the emotions and motivations of an individual participating in a "dialogue" with a computer may be influenced through various forms of group interaction mediated by a computer; b) that objective data on autonomic parameters can be used to control the intellectual activity of an individual participating in a "dialogue" (the reference is to a special type of feedback in the man-computer system). In this case, inasmuch as the basic difficulty of making practical use of autonomic data lies in the polyfunctional origin of these data, we hypothesized that concrete motivational mechanisms influence the way the subject differentiates those autonomic parameters which are significant from the standpoint of certain controlling influences from those that are insignificant.

We developed the following new variants of the experimental methods on the basis of these hypotheses: 1) a special effort was made to create conditions favoring arisal of the motive of competition with the computer in subjects participating in a dialogue with the computer. For practical purposes this was competition with other participants of the experiment, mediated by the computer. This process was controlled by varying the computer's evaluation responses; 2) more-flexible forms of influence upon human emotions and motivations were studied in experiments in which the moments computer responses were furnished to the subject were coordinated with a concrete functional state of the subject, as he worked on the experimental assignment.

Use of procedures of this type allows us, from our point of view, to exercise flexible control over unformalized processes in human activity. The effectiveness of these processes may be raised not only by capitalizing on certain potentials of modern computers (such as their tremendous memory, their high speed and so on), but also by activating, as much as possible, the specific mental potentials of the subject participating in a "dialogue" with the computer.

All of the computer programs were written in PL-1 for a YeS-1020 computer. The experimental methods and the data obtained are described more concretely below.

Investigation of the Production of Possible Goals During an Individual's "Dialogue" Interaction With a Computer. Description of the Experimental Method.

Everyday objects with which the subject was well familiar (pencil, match, chair) were named as the objects in the series of preliminary experiments having the purpose of studying production of possible goals. As was noted earlier, this procedure is often used in studies of the psychology of creativity. The subjects were given the following four instructions successively.

Instruction S1: "The object is...(the name of the object is given). Try to name as many properties of this object as you can."

Instruction S2: "The object is...(the name of the object is given). Try to name as many unique properties of this object as you can."

Instruction P1 (revelation of possible goals without the use of a computer). "Imagine that you are an analyst and that...(the name of one of the objects is given)...is the object you are to analyze. What problems could you state in connection with studying this object? Try to name as many problems as you can."

Instruction P2 differs from the previous instruction only by the statement: "Try to name as many original problems as you can."

The subject worked in accordance with each of these instructions until he gave up three times. After the first time he gave up, he was given the additional instruction: "Think a little more," and after the second time he was told: "You have come up with few properties (problems), think some more." If the subject did not give up, a time limit was imposed (1 hour).

We recorded the following on data sheets for the experiments: 1) the concrete products the subjects produced while fulfilling these instructions (these data permitted several conclusions on the typical features of the field of possibilities revealed by each of the subjects); 2) the time spent on each instruction; 3) the number of times the subject gave up. The line of reasoning of the subjects was recorded right during the experiment (with a tape recorder), and following the experiment as an unprompted report. Some additional parameters of analysis were introduced in correspondence with the hypothesis, mentioned above, that a certain relationship exists between production of the statements of P-goals of analyzing a certain object and revelation of the properties of this object: the properties and the combinations of properties used by subjects in their P-goal statements; the concrete procedures used by the subject to transform the property statements into P-goal statements. Moreover we analyzed the frequency with which certain properties, combinations of properties and procedures appeared in the activity of the subjects.

Sixty subjects participated in the preliminary series of experiments (students of a vocational-technical school and VUZ graduates). The results were used not only to develop the computer programs but also for comparative analysis of the specific ways P-goals are produced in traditional conditions (without a computer) and in "dialogue" interaction with a computer.

In the main series of experiments the subjects were first given two of the instructions described above--P1 and P2. Immediately after the subjects completed these instructions (after they gave up the third time) they were asked to use the help of the computer. In their reports, the subjects usually indicated that by the time their resources for revealing the field of possibilities had been fully exhausted and that they could not think of any more problems--original ones all the more so.

Experiments with the computer were conducted as follows. Some of the subjects (the control group) actually interacted with the computer, while the rest worked with an autonomous display system (ADS). In this system, the work of the computer was simulated by the experimenter using computer data acquired earlier. The ADS system was developed by V. B. Ryabov and Yu. A. Subbotin of the USSR Academy of Sciences Institute of Psychology. Its use saves computer time necessary for studying the features of "dialogue" interaction between man and computer.

All subjects were given identical directions and instructions--both those actually interacting with the computer and those working with the ADS. Thus all subjects were given the following direction before the main experiment: "Now you will work with the computer. You will receive all necessary instructions from it. The experimenter will be here only to see that the equipment operates properly; therefore you are not to ask him any questions during the experiment." Moreover the subject was asked to explain his actions aloud as he worked. These statements were tape-recorded.

Then the following assignment was given to the subject via a computer-display linking unit (in the autonomous display system) or a typewriter console (in real interaction with the computer).

Instruction PM1 (statement of P-goals in a "dialogue" with the computer).

> Let us continue. I will now be working together with you. We will formulate the problems of analysis in relation to the same objects. I can work in the following modes:
>
> 1) "Original property"--I provide you with a property which appears original to me, and you formulate the problem you associate with this property;
>
> 2) "property"--the same as mode 1, but the property is random;
>
> 3) "combination"--the same as in the previous modes, except that the single property is substituted by a combination of properties which must associated with one problem;
>
> 4) "problem"--I formulate a certain problem of analysis myself, and you must formulate another in response.
>
> Tell me which mode you would like to work in, and then rank them in order of preference. You can do this simply by typing their numbers.

We intentionally described the "problem" mode in the instructions in this ambiguous way so as to not reveal the extent to which the problems provided by the computer and those produced by the subject themselves must be related. The preliminary experiments themselves showed that this ambiguity produces a number of interesting observations associated with the attitude of the subjects toward the computer's "hinting."

After the subjects rank the modes, the computer displays the following message by means of the appropriate linking unit: "Please type the name of the mode in which you wish to work now."

After this instruction is fulfilled, the computer may answer the subject in the following fashion.

If the "combination" mode is chosen, it transmits the message: "How many properties must this combination contain? Your answer should be a number." The subject types a number, after which the computer gives him a randomly selected combination containing the quantity of properties prescribed by the subject .

If the subject chooses the "problem" mode the computer querries: "What sort of problems do you want--'crazy' or 'intelligent'?" If the subject selects "intelligent" problems the computer randomly selects one of the problems contained in a special problem library storing a number of computer statements, and problems suggested earlier by other participants of the experiment. If the subject selects "crazy" problems the computer produces them itself following an algorithm we developed specially. We called these problems "crazy" because the selectivity built into the computer, which is based on a probability procedure, often produces extremely unexpected computer formulations of problems in this mode.

After the subject transmits a problem he has formulated to the computer while working in a certain selected mode, he receives the following message: "Let us continue. Is the mode to remain the same? Answer yes or no." In the case of a positive response the work goes on in the former mode, and in the case of a negative one an additional question is asked: "In what mode would you like to work now?"

Considering that there are four modes of work and 120 properties, revealed on the basis of the preliminary experiments and written into the computer memory, the potential for producing the rudiments of possible goals attain astronomical proportions, and therefore we terminated the experiment after a certain amount of time (2 hours) or after the subject gave up just once. The following items of information were recorded on the experimental data sheet for each subject: a) a complete transcription of the "dialogue" between the subject and the computer; b) refusals to continue the work; c) the temporal characteristics of the "dialogue" (intervals between the typing of different messages, the typing time, the time used to rank the modes and so on); d) the subject's reasoning aloud; e) the reports given by the subjects after the experiment. Moreover the subjects were asked to rank all modes once again after the experiment.

Forty-five subjects participated in the main series of experiments--college students, high school students in their senior years and professional computer users.

In addition to the main series there were two supplementary series. In the first we studied the conditions under which subjects felt a need to appeal to the computer for assistance. Considering the limited possibility of modern computers for analyzing messages written in natural language, in this variant of the method we used a simplified model, substituting the naming of the possible goals of analyzing a certain object by one of the components of this process, mainly that of revealing the properties of the same object.

The subjects worked in accordance with three instructions given in succession. The first two were those described above, S1 and S2, concerned with naming the properties of a certain everyday object (in this experiment only one object was chosen--"chair"). After the subject gave up for the third time in his work on the last of these instructions, he was told that all of the properties he named had been fed into the computer, and that he was now to work together with it (these experiments also involved both real interaction with the computer and the autonomous display system). Then the following message was transmitted from the computer via the linking unit.

Instruction SP1: "We will now work together. I will provide hints to you. I will name one property which you have not named yet, and then you will name other properties. If you need another hint, simply type the word 'hint'."

The experimental time was limited--1 hour if the subject did not give up. The experiment was also terminated if the subject gave up at least once during this time.

As the preliminary experiments with this method showed, the word "hint" was unpleasant to most of the subjects. Consequently a certain conflict was created between an arising need for assistance and the form in which it was offered.

Twenty-five subjects took part in this series of experiments--college students, high school students in their senior years and professional computer users.

The second supplementary series of experiments had the purpose of studying possible approaches to solving the important problem of evaluating the productivity of goal forming processes.

In order to clarify whether or not use of the computer causes a certain increase in the productivity of the goal forming activity of the subject, we had to make a comparative analysis of the productivity of this activity in relation to subjects working in traditional conditions (without a computer) and in "dialogue" interaction with a computer. The main difficulty of this analysis lay in the absence of commonly recognized methods by which to evaluate the productivity of goal forming processes. The total number of possible goals produced and the percentage of acceptable variants are often used as possible quantitative criteria characterizing how optimum this process is. The most acceptable variants, meanwhile, are revealed by expert methods, since evaluation of goals is totally unformalizable.

In the experimental method we developed, to evaluate the productivity of goal forming processes we used both the characteristics of the process itself of producing possible goals and certain characteristics of the end products of this process--statements of goals of analysis, with which the subject's activity ended. In this case the quality of these statements was also evaluated by expert methods, which necessitated inclusion of yet another supplementary series of experiments. As we know, the results of an expert inquiry depend significantly on the concrete procedure of inquiry, and therefore we varied the experimental instructions in order to arrive at the best-substantiated evaluations.

First of all we were interested in whether or not any sort of qualitative differences exist in the goals stated by the same person in different conditions--independently or jointly with the computer. This in turn necessitated revelation of criteria used by the subjects to evaluate the quality of P-goal statements.

The two following variants of the expert procedure were employed: a) evaluation, by a certain group of experts, of possible goals formulated by a certain subject (the author); b) evaluation of these same goals by the author himself, now playing the role of expert. This made it possible not only to obtain the subjects' evaluations of the results of their own activity but also to compare the author's evaluations with the opinions of other experts.

In each of these variants the subjects ranked three sets of statements of possible goals. First they ranked the statements of goals produced by some individual independently, then they ranked the statements of goals they formulated during work with the computer, and then they ranked both types of goal statements together. A week later this ranking procedure was repeated in order to reveal the stability of the preferences of the experts. Two types of instructions were used in the experiments, differing in the means by which the ranking criteria were presented.

Instruction R1: Subjects fulfilling this instruction were simply asked to order each of the indicated three sets of statements of possible goals into a single series by preference. After the ranking was completed, the criteria by which the subjects ranked these statements were determined by questioning the latter.

Instruction R2: Before performing the ranking procedure, each subject was asked to name all possible criteria by which to evaluate P-goal statements. For this purpose the subjects were told to consider two imaginary situations in succession.

The "supervisor situation"--the subject was asked to imagine himself in the role of a disinterested supervisor, one of whose functions was to evaluate the goals produced by his subordinates. The subject was asked to name all possible evaluation criteria which he would use in this case. The second situation was referred to as the "subordinate situation." The subject was to imagine himself in the role of a subordinate given the job of selecting the goal of his further work from a certain set of alternative goals offered to him. In this situation the subject was also asked to name all possible criteria of such a choice.

Then the subject was given two criteria--"problem importance" and "problem originality"--and asked to rank the statements of possible goals in relation to each of them. In one form or another, these criteria were usually already contained in the lists of criteria given by the subject himself.

Statistical treatment of the expert data included calculation of Spearman's rank correlation coefficients, concordance coefficients and evaluations of their significance (52). Moreover we used Wilcoxon's two-sample shift test (5). In addition to these standard methods, an algorithm of "paired" nonmetric analysis developed by V. S. Kamenskiy (51) was used for computer treatment of the expert data.

Because we used these methods for statistical treatment of the expert data, we were able to impose more rigorous requirements on our approach to the following basic objectives: 1) revealing the stable preferences of the experts in relation to a certain set of objects of ranking suggested by them; 2) revealing the consistency of the opinions of the experts (pairs of experts and the entire group as a whole); 3) revealing the possible preference for some group of objects in the set of all objects of ranking.

All subjects of the main series took part in experiments performed in accordance with this method--45 authors and 18 experts (VUZ students). In this case 22 authors and nine experts fulfilled instruction R1 and the rest fulfilled instruction R2. The authors ranked only their own statements of the possible goals. Each expert completely repeated all of the ranking procedures described above, which were also completed by the author of the problems. For this purpose he was given a set of cards with one problem statement typed on each. The expert was not given any information as to precisely who the author of these statements was. After he ranked the problems of all authors, problems that were supposedly written by different people were given to him, though this time not on cards but on individual sheets. In reality, these problems had been revealed by the same person but under different conditions (independently and with the help of a computer). The expert was asked to state his judgment concerning these people on the basis of the statements of possible goals they produced. These "verbal portraits" were also considered in the analysis of the obtained data.

Analysis and Discussion of Experimental Data. General Features of Production of Possible Goals of Analysis

The results revealed two mutually associated means of formulating possible goals of analysis. In the first case the subject, who possesses certain *a priori* knowledge of the general goals of transforming objects of analysis, initially formulates these goals and then in a sense seeks properties corresponding to the former. For example a subject might note: "First of all I need to determine what in the object should be improved," after which he produces a statement of the following sort: "Improve property X," "Determine if property X would improve if property Y were changed," and so on.

The second method of goal formation was directly opposite to the first: Contrary to the first situation, the subject first revealed a particular property of the object and then thought about "what could be done with it"--that is, he sought a more-general goal permitting him to transform his property statement into a problem statement. In a number of cases the problems were generally formulated as "properties with a question mark." In this case the subjects noted that the expanded statement of this property in the form of a problem is self-evident, for which reason it need not be written out.

> Subject A.M. offered the following wording for a possible goal in response to instruction P1: "Presence of sap in the wood"

(the object is "chair"). Responding after the experiment to a question from the experimenter regarding this formulation of the goal, the subject said: "The main thing is to reveal a problematic property, since the subsequent expansion of the problem statement would be standard."

In this case the subject believed that the expanded statement would apply to an entire class of problems such as: "Analyze the wood for the presence of sap," "Reveal how it influences the quality of the wood and of the article itself, especially its processing," "If it has a negative influence, then find out how this shortcoming could be corrected,"--that is, an entire class of P-goals.

It should be noted that in addition to the two means noted above for producing the statements of possible goals, others existed as well. Thus formulation of problems on analogy was a rather typical phenomenon: The subject adapted certain problem statements known to him earlier to a new object given in the experiment.

Study of P-goal production is inseparably associated with revealing the criteria for optimization of this process. As was noted earlier, the total number of P-goals formulated by a subject in an experiment could serve as one of the quantitative indicators. This indicator is often basic to a number of known, applied methods (24). However the experimental data we obtained showed that this characteristic depends significantly on the concrete type of goal forming process. An example in which the subject named only a single problematic property rather than formulating a P-goal was given above. In this case he had in mind an entire class of problems which he did not name, believing that they were self-evident.

Moreover many subjects working on instruction P1 gave not just unrelated goals but a certain hierarchy of goals (Table 1)--that is, first they distinguished certain universal goals as the general directions of analysis, and then they broke them down into subgoals. In this case the system of universal goals developed in application to one of the objects given in the experiment was often carried over by the subjects to other objects without significant modifications, though the subgoals could be different in these cases. Some subjects working with second and third objects even tried to generalize these systems of universal goals.

Table 1

Group of Subjects	No. of Subjects	No. of Subjects Producing a Hierarchy of Goals
1 (college students)	20	12
2 (professional computer users)	5	4
3 (high school students)	20	7

The following happened in regard to the total number of possible goals formulated. Subjects who built hierarchies of goals often noted that the number of subgoals in their hierarchy could be very large, and that in principle they could continue this work for a rather long time. With additional stimulation by instructions, however, following the first and second time that these subjects gave up, all of them were hardly able to increase the number of universal goals they had formulated before. Growth in the total number of goals occurred mainly due to an increase in the number of subgoals in the hierarchy (Table 2).

Thus from our point of view in such a situation it would be unsensible to use only the total number of formulated goals as a quantitative criterion for assessing the goal forming activity of all subjects. A more elaborate analysis to reveal the features of the process itself of forming possible goals must be conducted.

Table 2. Average Number of Universal Goals and Subgoals in Goal Hierarchies Created by the Subjects

Indicators	Group of Subjects: 1 (College Students)	2 (Computer Users)	3 (High School Students)
No. of universal goals	4.9	3.6	4.3
No. of subgoals	7.5	4.7	8.1
After first stimulatory instruction:			
Enlargement of the number of universal goals	0.3	0.2	0
Enlargement of the number of subgoals	5.5	4.2	6.4
After the second stimulating instruction:			
Enlargement of the number of universal goals	0.08	0	0
Enlargement of the number of subgoals	4.7	3.9	4.1

Table 3. Average Numbers of Original Universal Goals and Subgoals

Indicators	Group of Subjects: 1 (College Students)	2 (Computer Users)	3 (High School Students)
Original universal goals	0.25	0.2	0.27
Original universal subgoals	3.42	2.7	2.4

In regard to the number of original goals (the naming of a given goal by only one subject of the experimental group was chosen as the criterion of originality), we also felt it suitable to analyze the originality of universal goals and subgoals separately. However, the following circumstance should be considered here.

Despite the certain similarities in the ways the subjects built their goal hierarchies, some subjects exhibited certain differences connected mainly with the amount of detail in their goal systems. Thus different subjects could place the same goal at different levels in their hierarchies--that is, a goal which is universal to some subjects may be treated as a subgoal by others. Considering this circumstance we said that universal goals were original only if the goals were not encountered among other subjects as either universal goals or subgoals. We can use some of our data as an example (Table 3).

The data in Table 3 indicate that universal goals were relatively standard as basic directions of analysis. But growth in the number of original subgoals often depended significantly on whether or not the subject independently decided to develop the basic directions of his hierarchy of goals in greater detail.

One other important fact should be noted. As the experiments showed, subjects who built goal hierarchies basically used the former of the two goal forming methods (formulation of more-general goals followed by selection of concrete properties) to build their universal goal hierarchies. But subjects who did not make a special effort to build goal hierarchies exhibited use of the second type of goal forming process much more frequently. It would be interesting to note that for most of the subjects, it would be easy to organize their goals into such a hierarchy; moreover when these subjects went on to other objects as required by the experiment, it was mainly the "universal" goals which they carried over to other objects, even though they did not make a special effort to distinguish these goals as universal. A third group of subjects created goal hierarchies for other objects (one created a hierarchy for the second object and two created hierarchies for the third). Therefore in our analysis of the results of their activity we were able to compare their hierarchies of goals. Such analysis made it possible to reveal the following features.

As was noted earlier, subjects who did not make a special effort to build a hierarchy of goals usually employed the second type of goal forming process--that is, they first analyzed the properties of the object and then sought the P-goal statements corresponding to them. In this case there was no clear influence of a rigid hierarchy of universal goals, and as they worked on the properties of the objects, the subjects sometimes discovered original directions of analysis. But such cases were few in number.

The obtained data also showed that subjects could very rarely "divorce" themselves from a certain practical use (including a nontraditional use) of the object presented in the experiment, and as a rule, on revealing a certain property, they did not limit themselves to formulating "purely analytical" goals. Despite significant difficulties they continued this process until such time that they revealed the corresponding practical significance of these goals. Thus the analytical goal was in a sense a stage along the road to a certain practical goal contained within the former.

Only a few subjects out of all of the experimental groups (12 out of 45) revealed possible goals of analysis outside the traditional uses of the object or in general not connected with any of its concrete uses. It would be interesting to note that out of all of these subjects, only one built a hierarchy of goals.

The obtained data may be supplemented by results from the preliminary series of experiments. In these experiments, prior to instruction P1, concerned with problem statement, the subjects were given instruction S1, by which they were required to name the properties of the object. We hypothesized that those subjects who stray beyond the framework of the traditional uses of the object in fulfilling the instruction of naming the object's properties, and who reveal nontraditional uses as, for example, functional properties or who name certain "internal" properties of the object which cannot be observed directly, but about which conclusions could be made on the basis of scientific knowledge, as well as properties associated with this object's interaction with the environment (for greater detail about this classification see (11)), would display the same sort of originality when formulating problems. This hypothesis was based on the assumption, described above, that a close correlation exists between production of possible goals of analysis of a certain object and revelation of the properties of the same object, and the assumption that the influence of the "psychological barrier of past experience" upon the same subject fulfilling instructions P1 and S1 should be extremely similar if not identical.

The results of experiments conducted to test this hypothesis showed that subjects who had formulated problems outside the framework of the object's traditional use did in fact as a rule display the same originality when revealing its properties. However, even among those subjects who displayed a certain degree of originality when fulfilling instruction S1, only a few (about 30 percent) went beyond the traditional uses of the object in fulfillment of instruction P1. The influence of the following factors is doubtlessly evident here: the type of goal forming process, the continuity of the goal producing processes and their critical evaluation, change in attitudes upon transition to a new instruction, to include attitudes associated with traditional ideas about the object. The system of universal goals stated by subjects who built goal hierarchies was often so "rigid" that it would not permit them to subsequently go beyond the framework of the object's traditional uses. In other cases universal goals were stated in a form which provided a convenient out (for example a statement such as: "Study the possible uses of the object," in which the functional name of the object was formally left "open"). However, when wording their subgoals the subjects often limited themselves to just the traditional uses of the object.

The experimental data showed that in these cases different sets in the activity of the subjects had different influence. Thus under the influence of sets connected with traditional uses of the objects the subject might unconsciously "close" "open" characteristics (78) when formulating universal goals. Sometimes, incidentally, this process was partially recognized by the subject, as manifested in the uniqueness of his critical evaluation of the formulated problems. As an example a subject might deem, as important and suitable, only those problems which are directly associated with the traditional uses of the object, and discard those statements which are less important in his opinion. "Purely analytical" problems were also frequently discarded if the subject could not find the appropriate practical application for such problems.

We should also note the influence exerted by differences in the definition of words contained in the instructions (for example the word "problem") and by reformulation of activity goals in connection with transition to new instructions (transition from instruction S1 to instruction P1) which was associated with development of new self-imposed limitations by the subject (this issue is discussed in greater detail in (11)).

The influence of different sets and self-imposed limitations was also manifested in the following. A comparison of the list of properties drawn up in response to instruction S1, which specifically oriented the subject on this, and the list of properties used in formulation of problems showed that the overlap of these lists could be highly insignificant--that is, the subject might reveal new properties with difficulty, and at the same time fail to use the large reserve represented by the properties he had already revealed (Table 4).

Did this mean that there are certain special "problematic" properties in the objects of analysis? To answer this question we performed the following experiment. The experimenter read a list of properties of an object which the subject had revealed earlier in fulfillment of instruction S1, specifically oriented to this purpose, but which the subject did not use to formulate the problems (instruction P1). Then the subject was asked to come up with problem statements in relation to each of these properties. All subjects participating in the experiment easily completed the assignment.

Thus this limitation was not fundamental in nature, being instead the consequence of certain self-imposed limitations arising in the course of goal formation itself. Moreover there can be no doubt that an influence is also exerted by a large number of other psychological factors, ones which cause the subject to stop producing P-goals despite the fact that his potential resources in this direction are far from exhausted. A typical indication that these factors exist is the possibility subjects have for producing new property and problem statements after giving up their effort.

The experimental procedure was structured in the following way: First the subjects revealed the properties of the object or formulated the possible goals of its analysis (instructions S1 and P1). After they gave up three times, they were asked to name only the original properties of the object or the problems associated with them (instructions S2 and P2). Most of the subjects (about 60 percent) refused to follow these instructions. The refusals were motivated by the fact that during fulfillment of instructions P1 and S1 they had already "completely exhausted their resources" and that they could not think up any more new problems or properties--original ones all the more so. The fact that many of these refusals were sincere may be judged from the significant increase in temporal intervals between the properties (and problems) the subjects named as the experimental assignment approached its conclusion. Still, some of the subjects never were able to fulfill instructions S2 and P2. Many of them fulfilled these instructions with great difficulty and with minimal productivity. Only one subject revealed an additional ten new properties and eight possible goals, and the averages for the other subjects were significantly lower: 3.2 for properties and 1.6 for problems.

At the same time these subjects noted in their reports that they could have named many more properties and problems. For them to do so, all they needed was "a slight hint," "a push into a new direction of thinking," and so on.

Table 4. Comparative Data for the Total Number of Properties Which Were Revealed by Subjects in Experiments With Instruction S1, Specially Oriented to This Purpose, But Which Were Not Used to Formulate the Possible Goals of Analysis of an Object (Percent)

Subjects	No. of Subjects	No. of Properties		
		Object 1	Object 2	Object 3
College students	20	70.6	62.5	58.3
Students of vocational-technical schools	20	57.4	43.4	66.7
VUZ graduates	20	61.1	54.4	72

And so, as subjects produce P-goals, they work in the presence of various limitations, such that many of their potentials for analysis of the field of possibilities they reveal remain unexplored. We noted the following among these limitations.

1) Limitations associated with the types and features of goal forming processes--for example limitations elicited by erection of a "rigid" system of universal goals.

2) The framework of traditional ideas about the given object of analysis (its functions, its uses, and properties and problems which would be significant from this point of view), instilled into the subject by past experience. This often hindered the subject from using his available knowledge on properties of the object insignificant to its traditional uses, on new means of its application and sometimes on the possible modifications that can be made of the object without straying beyond the framework of traditional use.

Thus our experiments were conducted with the participation of a rather large number of specialists in chemistry and physics; however, only a few of them utilized their professional knowledge to reveal properties of the object and to produce possible goals. They explained this in their reports by saying that they could not see the everyday objects shown to them in the experiment as professional objects of analysis.

We were greatly interested in making a comparative statistical analysis of properties revealed by the subjects in fulfillment of instruction S1 and properties used by them directly to formulate P-goals. The concrete influence of the framework of traditional ideas about the object of research may be determined graphically. As we had hypothesized, those properties which were significant to traditional use of the given object (zone *I*, Figure 4) appeared most frequently among the named properties. It should be considered in this case that the same property could be used by subjects in several statements. The limitations imposed by traditional use of the objects of analysis manifested themselves in particular as a certain degree of selectivity in choosing the properties of the object used by the subject to formulate P-goals.

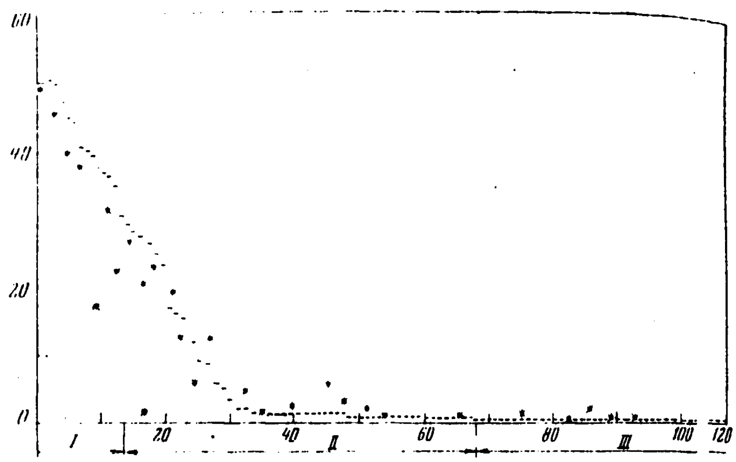


Figure 4. Frequency Distribution for the Same Properties of a Given Object Named by a Group of Subjects (Instruction S1, First Object): Asterisks denote the frequency of properties used by the same subjects to formulate P-goals (instruction P1), while hyphens represent the frequency of properties named by subjects in fulfillment of instruction S1.

Despite significant differences observed in the lists of properties revealed in fulfillment of instructions S1 and P1 by each subject, the frequency distributions of these properties for the group as a whole turned out to be extremely similar. Moreover if a subject used not one but two or more properties in the statement of a P-goal, analysis of the experimental data showed that in this case he was highly selective in his choice of property combinations.

3) The subjective attitude subjects displayed toward their activity. There is an unbreakable relationship between the evaluation process and the goal production process. We can also include within this category of limitations the low self-assessment given by a number of subjects to their possibilities for independent goal production, and the fear of going beyond one's competency.

The results show that if we are to study the influence of these factors on goal formation, we would have to reveal the subjective criteria used to evaluate the goals. We made a special analysis of this problem, as will be described below; for the moment however we will cite a number of examples confirming the important role of such evaluation to goal formation.

> Subject A.F.: "I was perpetually worried about getting carried away and talking nonsense. I was unable to concentrate all of my attention on thinking up problems, because I could never get my mind off of whether I was talking nonsense or not."

> Subject L. Zh.: "Very many problems came to mind, I wanted to dig deeper into them, the work was interesting to me, but the problems I came up with did not seem very important. At work,

> it is difficult to do those tasks which are important only to yourself, since they have to be completed in an atmosphere that tells you your work is not really necessary. I left out many problems which in my opinion would not be interesting to others. At work, things are simpler, because I deal with objects that are well known to me--that is, I know perfectly well what is important. I always keep it in my mind that I must maintain an awareness of this importance. In some ways this creates obstacles, but in others it reduces the amount of problems I have to consider."

Thus a subject may also reduce the field of possibilities he analyzes by fully conscious selection of the P-goal variants he produces. The criteria of such selection are highly diverse. As an example possible goals can be evaluated not only as interesting or uninteresting to the subject himself but also from the standpoint of their social usefulness.

4) Subjective interpretations of both the instruction as a whole and its individual words. The boundaries of the field of possibilities analyzed by the subject depended on the specific interpretation the subject gave to his assignment: He may supplement or reword the instruction, injecting new components not contained in the text of the assignment. As an example many subjects felt it necessary to view the presented object as a whole, without breaking it up into its parts (even though this was not stipulated in the instruction).

All combinations of the factors listed above are possible as well. Moreover the subject was not always generally able to explain precisely what obstacle hindered his work, though the fact that such interference did exist was communicated in the subject's report (thus limitations imposed on production of possible goals could also be differentiated in terms of the degree to which they are recognized by the subject himself). Here are some specific examples.

> Subject T. G.: "A lot more problems came to mind than I wrote down. They seemed to fade away. I was unable to state them not because I was scared what someone might think, but for some other reason. Generally, it always seemed to me that I was doing something wrong, that I was making a mess of things, and it was because of this that I found it hard to work."

> Subject O. V.: "I know that I came up with very few problems and that they were all really quite uninteresting. Something was bothering me--I don't know what. Maybe it was that I don't use these objects very often (!). If I used them more often (!), perhaps I would have come up with some sort of ideas. But the way things stood, it was very difficult for me. I could not see anything new that I could do, and most importantly I could not come up with anything that would be useful." When the experimenter asked a question concerning the fact that the subject doubtlessly makes frequent use of the everyday objects presented in the experiment, she replied: "What I meant was that these objects have never had anything to do with my professional work. Yes, I do in fact use them often, but I have never thought about them deliberately."

We attempted to reveal a certain "best" group among the subjects participating in the experiment, using the following characteristics: never giving up, a large number of produced goals, statement of goals which are beyond the traditional uses of the object and which are not directly associated with any of the object's concrete uses. Out of all of the participants of the experiment--there were 130 if we include the preliminary experiments--only six subjects fell into the "best" group. We were interested if the limitations discussed above were present or absent in these subjects, and what their distinguishing features were. The results showed that such features could include: loose restrictions in terms of the framework of traditional ideas about the object of analysis--attempts at seeking something new even in that which is traditional, at seeing any object with other eyes, at applying one's professional knowledge to this object. We also noted unique features in the concrete types of goal forming processes employed--a desire to formulate as large a number of universal goals as possible (this desire appeared in recognized form when special hierarchies of goals were created) and transformation of all subgoals into sources of new goals. We also observed greater interest in fulfillment of assignments characterized by the greatest complexity and ones independently formulated by the subject for himself.

Here are some examples.

> Subject O. Ye.: "The most interesting thing was to find universal directions of analysis, because once they are found, it is easy to come up with subproblems."

> Subject M. L.: "At first, it was easy to think up problems, but that was not very interesting. But as soon as it became difficult to think them up, things got interesting, because nothing more would come to mind but I knew that their had to be some others, and I immediately felt that there was hope for new avenues of thought--after all, I had already exhausted all of the possibilities on the surface."

However, we do need to define the concept "best" group more specifically. We had reason for placing this word in quotation marks. The fact is that a subject's capability for producing a large number of interesting, original and important goals may not be directly dependent on the productivity of his real activity. Thus one of the subjects in the "best" group noted in an interview with the experimenter that in his job, he is bothered a great deal by an overwhelming flow of ideas--formation of a tremendous quantity of secondary goals during solution of some concrete problem.

As an example, here is an excerpt from his report.

> Subject O. Ye.: "When I perform experiments (I work in experimental physics) various 'incidental' effects constantly nag at my attention. As a consequence it takes enormous will to concentrate on the initial task, and my attempts at doing so are far from always successful. As a result I begin to expand the initial problem in an attempt to include all of these secondary goals within it, and I end up with such a mess of bits and pieces of different goals that I can't make any sense of it all."

Thus the results confirmed the hypothesis that a certain relationship exists between formulation of possible goals of analyzing a certain object and the process by which its properties are revealed. The analysis revealed the following: existence of at least two types of processes with which to come up with such statements; presence of a certain hierarchy of goals named by the subject; confinement to only quantitative criteria for determining whether or not the goal forming process is optimum; a need for revealing the qualitative characteristics of both the process and the products of goal formation. We also revealed some factors influencing the quantitative and qualitative characteristics of goal formation. These characteristics were differentiated in terms of their positive and negative influence.

Characteristics of Production of Possible Goals in "Dialogue" Mode

We differentiated the following characteristics in our analysis: first, changes in activity elicited by procedures developed for the purpose of providing additional assistance to the subject and placed at the basis of the "dialogue" modes indicated above; second, changes in activity depending on the concrete type of interaction between man and computer in "dialogue" mode.

As was noted earlier, the computer programs were based on data from the preliminary series of experiments. All of the "dialogue" modes were developed in such a way that they would promote certain changes in the goal forming activity of the subject--in particular, by breaking down a number of the limitations that prevented broader production of P-goals.

The "dialogue" modes were oriented at the following changes in the activity of the subjects, in comparison with the traditional conditions of their work (without a computer).

1. When working independently (without a computer) the subjects exhibited at least two methods of producing their statements of possible goals. Use of the first method was often accompanied by construction of a "rigid" hierarchy of universal goals which hindered broader production of P-goals. The overwhelming majority of computer-assisted work modes (three out of four) were oriented on the second type of goal forming process (from analysis of properties to formulation of possible goals). From our point of view this orientation could promote weakening of the negative influence exerted by a "rigid" hierarchy of universal goals on the goal forming process.

2. Data from the preliminary experiments also showed that the choice of properties used by the subject in formulating his P-goals and of the concrete procedures by which to transform property statements into P-goal statements is distinguished by significant selectivity. Subjects often reveal certain classes of properties and then formulate problems without going outside the particular class, for example the class of properties characterizing the external features of the object--color, shape and so on. In these cases the wordings of the possible goals of analyzing the object can be highly similar. The subject used just a few "procedures" such as "studying...(property X)," "improving...(property X)" and so on. Choice of one property often predetermines the choice of the next; the same can be said for choice of "procedures" as well. All of this had a negative influence on the productivity of goal forming processes. We accounted for these characteristics of the activity of

the subjects when developing the "dialogue" modes. Thus we employed a random selection procedure in the "property," "original property" and "combination" modes. Properties belonging to the most diverse "classes" and having different probabilities of arising in the object were named to the subject in random order. Selectivity in choosing "procedures" and the properties corresponding to them in the algorithm at the basis of the "problem" mode was also weakened by employing random procedures and a highly insignificant number of restrictive rules that "prohibit" certain combinations of properties and "procedures." The consequent need for switching quickly from one class of properties to another and for analyzing unusual combinations of properties and "procedures" could promote revelation of new directions in the field of possibilities analyzed by the subject.

3. As the preliminary experiments showed, when an independently working subject formulates possible goals he utilizes properties which as a rule fall within an extremely narrow domain, mainly within zone *I* (Figure 4). For the most part these are properties associated with traditional uses of the object of analysis presented in the experiment. The number of times each subject strays beyond the bounds of this domain is usually small, but the total number of original properties revealed by a certain group of subjects could become significant (in this case an original property is defined as one named by only one subject in the group). The computer-assisted work modes allow the subject to utilize the generalized experience of many people, and therefore to work not only in zones *I* and *II* but also in zone *III* (see Figure 4) of the property distribution. Moreover a subject working in the "intelligent problems" mode may participate in a computer-mediated "dialogue" with other participants of the experiment, which also promotes expansion of the subject's ideas about the field of possibilities he is analyzing.

4. The preliminary experiments showed that subjects working independently (without a computer) rarely use more than three properties in a single problem statement; moreover the choice of properties used is distinguished by significant selectivity. In the "combination" mode the subject was given the possibility of working with a number of properties of his own choosing; moreover these properties are selected from the computer memory by random as well.

Let us now analyze the concrete modifications that occurred in the limitations on goal forming imposed by subjects working in a "dialogue" with the computer.

1. Changes Associated With the Parameter "Concrete Types and Features of the Goal Forming Process"

In distinction from previous experiments, not a single subject participating in the experiments with the computer built a hierarchy of goals, doubtlessly because of the characteristics of the modes. While in experiments without the computer (instruction P1) the subjects first formulated a certain system of universal goals and then broke them down into subgoals, the process was reversed in work with the computer. Moreover when formulating a goal at the lowest level of the hierarchy, the subjects often referred to the possibility of existence of goals at a higher level: "There is a problem of even greater importance here," "This is a partial goal" and so on, but in this case they were not always able to formulate these more-general goals. The reason for this lay not only in the specific features of the methods upon which the corresponding dialogue modes were based, but also, very importantly, in the concrete features of interaction between man and computer, particularly in the rhythm of communication between man and computer. As an example many subjects noted that although they often sensed the existence of more-important problems when working in a particular mode, they did not, using the words of the subjects themselves, try to "drag them up to the surface of their consciousness," instead suggesting simpler variants, since the more-complex problems required special thinking but the computer "was already waiting for a response" ("I did not want to break away from the rhythm imposed by the computer," "I felt uncomfortable making it wait").

It should be noted that the subjects made the independent decision, often contrary to the supplementary instructions from the experimenter, to transmit the messages to the computer as quickly as possible, and they noted that delays in transmitting these messages often felt unpleasant to them. This can be explained in particular by the fact that a number of features and stereotypes of the communication rhythm encountered in the evolved practice of communication with other people are carried over by the subjects to the new conditions--to those of a "dialogue" with a computer. This problem is considered in greater detail in (13).

Thus we need to differentiate a dual effect of the rhythm of communication with the computer on the goal forming process. A subject experiencing a subjective lack of time is unable to thoroughly work out the goals he formulates. On one hand this relieves the obstacle produced by the subject's tendency to be critical of his decisions, while on the other hand it promotes arisal of purely mechanical combination of characteristics; in a sense, the individual's activity becomes machine-like (likened to an "intelligent conveyer"). In this case the work of the subjects was essentially quite similar to the problem statement acquisition algorithm we developed (the "problem" mode).

2. Changes Associated With the Parameter "Framework of Traditional Ideas About the Object of Analysis"

A significant weakening of limitations associated with this parameter was observed when subjects worked in "dialogue" with the computer. This weakening was manifested in particular as a significant increase in the number of goals not associated with traditional uses of the object of analysis presented in the experiment (Table 5). Moreover we observed the appearance of analogous goals, ones only remotely associated with objects presented in the experiment--that is, the subjects actually strayed beyond the bounds of the instructions, which were adhered to strictly during independent work (without the computer). It should be noted, however, that violation of the traditional framework of ideas about the object of analysis was hardly a frequent occurrence. Thus many subjects working in the "original property" or "combination" mode often exerted significant effort in an attempt to adapt the most unexpected properties and the most senseless combinations of properties of the object to problems associated with its traditional functional use.

Table 5. Comparative Data Characterizing Expansion of the Subject's Ideas About His Object of Analysis During Work in "Dialogue" Mode

Subject Group	No. of Subjects	No. of Subjects Stating Possible Goals Not Associated With Traditional Uses of the Object: In Independent Work	In Work With the Computer
1	20	7	16
2	5	0	4
3	20	10	15

3. Changes Associated With the Parameter "Subjective Attitude Toward the Activity and the Self-Assessment of the Subject's Possibilities for Independent Goal Formation"

This group of factors deserves the most persistent attention, because the changes they experienced during "dialogue" with the computer quite distinctly reflected the influence of a number of psychological features associated with interaction between man and computer. In particular, these changes were connected with personification of the computer and with consequent arisal of special goals pursued by the subject during communicative interaction with the computer.

As was noted earlier, the activity of the subjects in the experiment exhibited a complex structure. Instructions given by the experimenter oriented the subject toward revealing the possible goals of analysis of a certain object. Consequently in this situation we are dealing with a case of consciously self-initiated goal formation (91); this does not exclude, however, the possibility of involuntary arisal of goals in the subject's activity. But goals voluntarily formulated by the subject do have the following unique feature. They are not directly associated with the motives of the practical activity; the subject limits himself only to naming the goals, and therefore we called these possible goals, or P-goals, in distinction from ones that are actually pursued.

However, besides these possible goals the subject also produced actual goals in the experiment. First, analyzing the instructions given by the experiments, a subject would reveal concrete goals of his activity in the experiment, transforming his assignment into "my own goal" (we will refer to these goals as M-goals). M-goals are precisely what orient the subject toward revealing P-goals. Second, the experimental situation includes elements of the subject's direct communication with the experimenter and computer-mediated communication with both the experimenter and other subjects, in the course of which special goals may also involuntarily arise (E-goals and C-goals). The characteristics of the way these "actually pursued" goals are produced have a significant influence on the productivity of P-goal formation.

Let us compare as an example a number of reports given by subjects after fulfilling instruction P1 (independent revelation of P-goals) and instruction PM1 (computer-assisted revelation of P-goals).

> Subject O. M. (instruction P1): "It was very difficult for me to formulate the problem. I kept thinking that whatever I did, I would not be able to come up with anything interesting, and even the elementary problems came to mind with difficulty."
>
> (Instruction PM1): "I could have given two or three problems and more for the same combination. I always had this urge to tell this to the computer (C-goal). It always seemed to me that it was giving me properties that were already known to fit the object, though randomly--that is, it probably already knows the problems associated with these properties, and it wants to receive as many of them as possible. I even wanted to ask it to give me a harder task (C-goal), so that it would know that I could handle it. Generally, I found the experiment very interesting this time. I would never have thought up all of these properties myself. I even felt sorry that the experiment had to end."

C-goals may perform different functions in the activity of subjects working in "dialogue" interaction. Thus they may distract the subject from his main goal or, on the other hand, as was demonstrated above, they may promote its attainment. Here is one more example.

> Subject G. T. (instruction P1): "It is very difficult for me to think of anything, I want to think of something original (D-goal), but I can't come up with anything" (the D-goal is unattainable).
>
> (Instruction PM1): "I like working in the 'original property' mode very much, because I wanted to learn as many of these original properties from the computer as possible (C-goal). It seems to me that this is the only way a person can come up with original problems. After all, originality cannot begin in a vacuum: You must have a certain amount of knowledge, and this knowledge must be good, and the computer can be an aid in this" (in the subject's opinion attainment of this C-goal would promote attainment of the D-goal).

Following are a few more interesting facts connected with the psychological characteristics of the subject's subjective attitude toward the computer in his work with it--namely with a problem important to man-computer systems, which may conditionally be referred to as the problem of division of responsibility. Thus many subjects in the experiments with computers in a sense delegated responsibility for the quality of the P-goals they produced to the computer. As an example one subject said: "The problem is generally not very interesting, but the computer is itself at fault for that: You wouldn't be able to come up with anything better for the combination it gave." In some cases the "quality" of the statement of a possible goal produced by a subject was dependent on his high trust in the knowledge stored in the computer (we examined this "overtrust effect" in greater detail in (11)): "The computer knows everything well," "The computer knows what it wants, so there is nothing to be worried about. If it names a certain property, it must be important." Here is a concrete example.

> Subject G. T.: "It is much more interesting and somehow easier to work with the computer, because there is some sort of reference point here. Most importantly, you stop wondering whether or not your being ridiculous, since the computer knows what it wants. I trust it or, should I say, what it knows."
>
> Another example. Subject F. A.: "It is more interesting and easier to work with the computer. When I was working alone I was always afraid that I would digress to nonsense. But the reason why it is more interesting to work with the computer has nothing to do with the fact that it is easier. Working with it, I was able to concentrate all of my attention on actually thinking up problems, rather than worrying about whether or not I was coming up with nonsense, because the material had already been evaluated by someone else. It is easier to evaluate what someone else comes up with than to come up with your own. What is called for here is an opinion. If the computer gives you something, then it also bears the entire responsibility for the material, and at the same time this gives me free rein--after all, I can always add something of my own to what the computer gives me."

All of these phenomena also have both positive and negative aspects. On one hand the subject receives the possibility for working with less restraint, for concentrating more attention mainly on the process of producing the problems, rather than on their critical evaluations. But on the other hand the possibility for passing the "responsibility" to someone else promotes production of highly superficial and sometimes simply meaningless problems.

Thus the analysis showed that in "dialogue" mode, changes occur in goal forming processes. These changes are elicited both by the concrete types of interaction involved between man and computer and by the methods embodied within the computer programs. We observed change in a number of limitations hindering development of the goal forming process: significant weakening of the influence of a "rigid" hierarchy of goals, expansion of subjective ideas about the object of analysis, a less-critical attitude toward the produced goals. These changes occurred under the influence of the following factors: a certain mode of communication between man and computer, personification of the computer, the possibility for utilizing the generalized experience of many subjects, arisal of special goals associated with computer-mediated communication with the programmer and other subjects, and the possibility for dividing "responsibility" when in "dialogue" with the computer.

The Need for Referring to the Computer and for Communicative "Intercourse" With It

As was noted earlier, the "dialogue" modes offered rather high possibilities for obtaining the "rudiments" for formulation of P-goals. Under these conditions the productivity of a subject working with the computer depends to a significant extent on arisal of a need within the subject to appeal to the computer for assistance. Otherwise these potentials may not be realized. Subjects should hardly be forced to work with a computer, especially when solving creative problems. Therefore we believe the stability with which the need for referring to the computer is expressed to be one of the principal indicators of the effectiveness of "dialogue" modes.

In the series of experiments we conducted using instruction PM1 (the "dialogue" mode), not only did none of the subjects refuse to work with the computer at any time during the experimental assignment, but also many of them even expressed the wish to continue producing P-goals after the experiment ended. The research showed that two groups of factors elicit the need for referring to the computer. These factors are associated with the external and internal conditions of the individual's activity in "dialogue" mode. An example of an external factor is the experimenter's instruction, while internal factors include a cognitive interest toward the computer's potentials and cognitive needs arising in the subject during his principal activity. The last factor is decisive to an evaluation of the effectiveness of the "dialogue" mode, and this is why we attempted to deliberately form a cognitive need in the subjects. One of the possibilities for doing so involved creation of external conditions which would stimulate internal factors.

The experimental procedure was organized in the following fashion: The subject was encouraged to continue his activity even though its furtherance would be difficult. All subjects began working with the computer only after they formulated some P-goals independently--that is, after they had partially exhausted their resources in this direction (after giving up for the third time). In this case, while working in one mode they named from one to seven problems, and then they once again referred to the computer for assistance, working in the same or in a new mode. In their reports, many of them noted that they could have produced more problems after the computer gave one property (or a combination of properties or problems), but these problems would have all been of the same type. It was namely for the purpose of changing the direction of problem production that they referred to the computer again.

The need expressed by the subjects for computer assistance was analyzed in greater detail in a special supplementary series of experiments based on the following method. The subjects worked in response to three instructions given in succession (S1, S2 and SP1) (see the description of the method). The first instructions were S1 and S2, which required the subject to name the properties of a certain given everyday object. After the subject gave up for the third time in his work on instruction S2, he was told that all of the properties he named had been fed into the computer, and he was now to work together with it (instruction SP1). All subjects worked with only one object, and they were given 10 hints--properties of the given object which had not been named by any subject in the group during work on instructions S1 and S2. On the average, subjects working with one hint named seven to eight properties (from 2 to 31).

Many subjects expressed a negative attitude toward the hints several times in their discussions of their work on the assignment in the reports they gave at the end of the experiment.

> Subject A. A. noted in his report: "It was hard working in this mode, I could not tear myself away from the hints in any way, but on the other hand I very much wanted to do without them. In general, I do not like being repetitive. I do not want to accept a thought that someone else tossed out as my own. All the time I wanted to think of something that was my own."

However, despite these negative emotions the subject nevertheless did appeal for assistance from the computer. This phenomenon cannot be explained just by cognitive interest in what the computer "knows," since to satisfy this interest it would have been sufficient to name just one property, while most of the subjects named significantly more properties after each hint.

In this connection we were especially interested in attempts by subjects to conceal their need for computer assistance from the experimenter. Various tactics were used in this case. Thus one of the widespread tactics was exaggerated and intentional demonstration of true or false C-goals before the experimenter. Here are some concrete examples.

> Subject S. Ye. (while reading the instructions and while working with the first two hints): "In general, I could work without the hints as well, I'm simply interested in what the computer knows (C-goal). Notice that I'm responding mechanically, almost without thinking." This same subject noted the following while working with his third hint: "Well, I need to show the computer that I can work without this help as well" (C-goal). After this he named 14 properties, of which 11 were associated with hints.

> Subject A. A. (before interrogating the computer for the third hint): "I could keep working with the previous hint, since I can still name many properties having to do with this object. I am asking for a hint only out of curiosity. I want to find out what the computer knows (C-goal). After the computer gave the next hint, he exclaimed: "That's no help, I can't think of anything else. I'm now in a worse position than I was before. I can't think of a single property more, so that I could ask for another hint."

Sometimes subjects tried to "debate" the originality of the properties stated by the computer.

> Thus subject O. L. notes: "All of the properties the computer has hinted to me were ones which I myself wanted to name while working on the previous instructions, but somehow I forgot about them. For practical purposes the computer was not hinting, but only reminding."

> After the first hint, subject G. V. turned to the experimenter: "You did not word the previous instructions correctly. You should have explained to me from the very start what sort of properties I was supposed to name, or at least the direction I was to go. Then there would have been no need for any sort of hints. Now I am forced to once again ask for hints to find out how else you confused me."

Thus the subject in a sense blamed the experimenter, who worded the instructions "incorrectly," for having to interrogate the computer.

But why did the subjects turn to the computer for help, and what was behind their demonstration of false C-goals? As was mentioned earlier, the experimental method was designed in such a way that they began working with the computer only after they had partially exhausted all of their possibilities for thinking up properties or for producing problems (after giving up three times). Under these conditions the process itself of thinking up new items was difficult for a number of subjects, and required a certain degree of mental exertion.

> Thus subject V. G. noted in his report: "First it was very easy to name the properties, and I did not need any information that would define the object more exactly. The properties were in a sense on the surface, and I named them almost without thinking. As fewer and fewer of these properties were left, I began to think more and more. Now it was difficult to come up with new properties. On one hand I felt that there were still many properties, while on the other nothing else was coming into my head. I began searching for a loophole of some sort, I tried to divorce myself from everything that I had said earlier, to broaden my understanding of this object--that is, to find some sort of new direction."

The same was true for a number of other subjects as well. How difficult it was for the subjects to work after the first time they gave up, and especially after the second time, could be judged not only from what they said during the experiment or in the reports, but also from the significant increase in time intervals between named properties. While initially these intervals did not generally exceed several seconds, toward the end of the experiment they increased to 5-6 minutes and more. This led to the conclusion that the subjects did not give up insincerely.

And so, on one hand the subject encounters certain difficulties in fulfilling the instruction given at the end of the experiment while on the other hand he is often quite interested in proving himself well in the experiment. The very fact that they had to resort to hints was, to many subjects, a confirmation that they were not working sufficiently well in the experiment. As a result the need arises for seeking new resources, a new direction for their thinking. It is with this goal in mind that the subjects turn to the computer for assistance.

This could be concluded from the statements of the subjects as well.

> Subject O. V.: "What a hint gives me is not just the name of some one property, but a certain direction for my responses. After all, I had not named these properties before because I had not been thinking in this direction."

> Subject G. V. : "A hint broadens the range of the concepts with which we had worked before the hint was given. It provides an exit from the limitations which we ourselves imposed. A hint provides new direction to my thoughts, one based on someone else's knowledge and opinions."

The experimental data show that in cases where subjects were sufficiently cognizant of the obstacles which were preventing them from successfully fulfilling the instructions, or where the possibilities for surmounting these obstacles with the help of the computer were analyzed thoroughly, "dialogue" interaction with the computer was most effective. This was expressed in improvement of a number of parameters characterizing the productivity of the subject's work in this mode (growth in the total number of properties thought up, and of the number of original properties and new directions). Moreover, in such a case the subjects expressed a stable desire to work together with the computer. A large number of negative emotions connected with the negative attitude of many subjects toward hinting were eliminated.

The way many subjects evaluated the hints themselves was interesting from the standpoint of the help they provided in this form of activity. Here are some concrete examples.

> Subject O. V.: "It generally seems to me that a hint has the best impact when it bears the least information. Such a hint is the least obtrusive, such that I could ignore it if I wanted to."

> Subject A. A.: "Almost all of the hints provided little help to me. They were very concrete, they referred to a very narrow direction of thought, and they could not be broken down into smaller elements."

> Subject L. A.: "For some reason I can never switch my attention immediately if I am thinking in a certain direction. This is why I need hints which would open up a very broad avenue of thought. After all, it is easier for me to narrow this avenue down than to broaden it."

Thus the subjects state very concrete requirements toward computer advice.

And so, what we are saying is that the subjects develop specific cognitive needs that are satisfied by interrogating the computer. These needs are associated with expanding knowledge of the object of analysis, surmounting limitations and seeking a new direction of thought. Cognitive needs associated with the subject's own evaluation of his activity, which in the conditions of computer dialogue assumed the form of the need for a computer evaluation of the subject's actions, are a special case.

> Thus subjects noted: "I wish that the computer would talk with me a little more, since I don't know whether it likes what I am doing or not. If it would talk a little more, perhaps I could get some idea of what it thinks"; "I wish that the computer would either praise or scold me, then I would work better"; "I wish the computer would evaluate my responses. It would be nice, for example if it said: 'That's interesting,' 'That's original,' 'There, you see, things are now beginning to fall into place.' It's hard otherwise, because you don't feel that real communication is going on and it's needed very, very much here."

Man's need for communication is an important psychological problem, and much research is being conducted on it today. Now that dialogue systems are enjoying intensive development, this problem is acquiring a new ring.

The experimental data showed that the need of the subjects for communication that manifested itself in man-computer dialogue was closely associated with the computer's personification. We revealed the following features associated with this phenomenon: 1) ascription of intellectual properties to the computer ("smart," "stupid," "reasons well" and so on); 2) endowment of the computer with conscious goals ("It deliberately gave me a hard assignment," "It wants to prove to me that it is smarter than me" and so on); 3) ascription of human emotions to the computer ("It won't be insulted," "So let it be unhappy," and so on); 4) arisal of a special class of C-goals in the subject himself ("It would be interesting to know how the computer learns," "I'll prove it to it" and so on).

The extent to which the personification phenomenon manifests itself doubtlessly depends on the training level of workers using the computer. Thus naive personification--"anthropomorphization" of the computer--is typical mainly of untrained computer users, though we may even occasionally encounter it among professionals working in this area. It should be noted that what we are dealing with in a large number of cases is not personification of a device but communication mediated by this device, communication with a programmer, a group of programmers, an experimenter and other subjects participating in this experiment. In this case when we hear the phrase: "I want to find out what the computer knows," the implication is essentially to find out what the unique features of the program are; however, even here it may be said that there are certain elements of personification.

Personification of the computer and the need for communication during work often led to a situation in which the subject began to imagine communication going on where there was none (especially people not prepared in this aspect). Thus one subject said the following in response to a combination of properties given by the computer:

> "That's mean, you've done it again, thinking that you've stumped me. But watch, I'll figure it out, and then I'll put you yourself on the spot."

This was manifested especially clearly by some subjects working in the "problem" mode--that is, in the most "intelligent" of all of the offered modes.

To demonstrate these phenomena more graphically, here is the record of one of the experiments as an example.

Experiment Record (Excerpt)

Subject T. R. begins working in "problem" mode after "original property" mode (after three interrogations of the computer).

Subject (types): Problem.

Computer: What kind of problems do you want: "crazy" or "intelligent"?

Subject (laughs): Now that's pretty funny. Just in case I better go for "intelligent," since this might be a trap. (Types): Intelligent.

Computer: What should be the optimum dimensions of a pencil?

Subject: Just don't think that you're going to lead me around by the nose. (Types): Develop a process for using a wood substitute. (Speaks): Now let's see how well you can think on your own. (To the experimenter): I want to find out if it will work out my own problem or if it will also think up something on its own, as I did.

Computer (after the subject asks for the same mode): Analyze the need for painting a pencil.

Subject (perplexed): But that's plagiary, and underhanded plagiary at that. After all, a coat of paint is something that covers the pencil lead. It answered in such a way that one could think that its problem is not associated with mine because it's talking about paint. But it's immediately evident that this is obvious plagiary. (To the experimenter): Tell me, does your computer get insulted very easily? I want to type out that this is plagiary. (Then she thinks up a problem and types): Analyze whether or not a leadless pencil could be created. (To the experimenter): I want to see whether or not its problem would be associated with mine once again. (When the computer asks for the work mode, the subject replies with irritation: "You don't have to be tricky, we're obviously still in the same mode").

Computer: Creation of a mechanical pencil writing in different colors.

Subject (laughs): How now, my precious, so you can't think on your own. Once again there's a connection with my problem--after all, this is a counter-problem to mine. I was going for a leadless pencil, and it wants more leads. O.K., this time I'll forgive it. I like the fact that it was able to worm its way out so well. Your computer does not lack a sense of humor. Good for it! (Types): Creation of an improved pencil for the blind. (Speaks): That makes me somehow feel a little ill at ease--this time I've borrowed from the computer a little. After all, a mechanical pencil and a pencil for the blind are quite similar, since they both have to be highly mechanical. Well, O.K., if it picks up on my ideas, I should be able to pick up on its ideas, we really should share. (She asks for the same mode, making the comment: "You yourself could have guessed what mode I want by now"). (To the experimenter): I wonder what sort of association it will come up with now--supposing it can't?

Computer: Change the shape for greater convenience.

Subject (speaks): I don't like this problem. It's kind of fuzzy; the computer's probably tired too. And anyway, that's not fair, the rules I have to work with are stricter. Now I'm going to think up a problem, and choose another mode; let the computer rest.

The results showed that personification of the computer influences the subject's activity in a certain fashion. Thus under the influence of personification, a subject may display greater activity in goal production, high responsibility for the quality of the goals and so on. However, under certain conditions personification could also disorganize the subject's activity, implying the need for a certain amount of caution in using this phenomenon as a means for optimizing "dialogue" interaction between man and computer.

We demonstrated that in the experimental situation under analysis, the need for referring to the computer was elicited by two groups of factors--external and internal. The experimental data confirmed the hypothesis that appearance of cognitive needs in the subject is the decisive factor in an evaluation of the effectiveness of "dialogue" interaction. In this connection we showed it possible to form cognitive needs that encourage the subject to refer to the computer by making certain changes in the external influences. We found that when subjects were encouraged by an outside source to continue activity which was made difficult at the given moment by the limited possibilities of the subjects themselves, they developed a need for assistance from the computer, even in the presence of a specially created conflict situation in which this assistance is provided in an "unpleasant" manner. In this case subjects react to the conflict situation by attempting to conceal their need for assistance: They express their real or false C-goals in an exaggerated and deliberate manner.

We revealed a special case of cognitive needs associated with evaluating the activity of the subject himself; in a computer "dialogue" these needs manifest themselves concretely as the need for acquiring evaluations of the subject's actions from the computer.

We also demonstrated that when an individual interacts with a computer, he develops a need for a certain form of this interaction (for "communication" with the computer), which in turn is closely associated with the revealed phenomenon of "personification of the computer." We described different types of personification, and we demonstrated their relationship to the user's training level and their influence on the activity of the subject engaged in "dialogue" interaction.

Selectivity in Using the Possibilities Offered by the Computer, and Evaluation of Concrete Forms of Their Realization

The subject's selective attitude toward concrete forms of realizing the possibilities offered to him by the computer is closely associated with the arisal of the need for communicating with the computer. This attitude is one of the manifestations of this need.

The productivity of creative activity depends on many factors (146,148). It would be difficult to imagine that someone could develop an optimum "dialogue" mode which would satisfy all subjects without exception. Moreover a certain amount of monotony in computer responses could also have a negative influence on the productivity of a subject participating in a "dialogue" with the computer. From our point of view a subject participating in creative activity together with a computer should be provided a certain amount of freedom in choosing concrete modes of "dialogue" interaction with the computer. Selectivity in utilizing the possibilities offered by the computer would be manifested in this case by the subject's choice of specific "dialogue" modes.

In the experimental method we developed the subjects could not only freely choose concrete modes of interaction with the computer, but they could also switch from one mode to another during their work. The experimental results showed that choice of modes was governed by the following factors: a) cognitive interest in the given mode; b) subjective evaluation of the difficulty of work in the given mode; c) subjective evaluation of the successfulness of activity in the given mode, using an independently formulated "success" criterion, which could be represented by a concrete goal of the subject's actions in the given situation; d) subjective evaluation of the possibilities for acting in a way other than that suggested by a hint--that is, the possibilities for maintaining the dominant role in independent goal formation, even when computer assistance is provided.

The factors listed above underwent modification during the experiment in accordance with change in the goals of concrete actions and with the evaluation criteria associated with these goals. We used these modifications to evaluate the different variants of the "dialogue" modes.

Thus in the stage of *a priori* analysis of the modes, the subject is able to predict the difficulty of work in a given mode, the possibility of successful activity in it and so on only on the basis of the description of the mode provided by the computer, the subject's own experience and his knowledge of the possibilities offered by modern computers. These *a priori* evaluations essentially predetermine the initial choice of mode. *A priori* evaluations may be rather persistent: Thus about 30 percent of all of the subjects worked in all of the offered modes, while the rest worked in only three, two, or even just one.

In the stage of *a priori* analysis, many subjects evaluated the possibilities of the computer in addition to evaluating the mode; moreover we found that these processes were close interrelated. Here is one of the most typical examples.

> Choosing a mode, subject L. Ye. commented: "I would like to try the "combination" mode but I'm afraid that it would be too hard. After all, the properties may not have anything in common, or they might be completely random. Yes, that's what the computer is most likely to do, since it can't make choices like a person could."

The "combination" mode was one of the most popular. Almost all subjects used this mode in this series of experiments, ranking this mode first or second in both *a priori* and *a posteriori* ranking. We in turn were interested in the reasons behind such high consistency in the opinions of the subjects. We can illustrate this with concrete examples.

> Making her *a priori* evaluation of the modes, subject O. M. commented: "I'm choosing the 'combination' mode because it seems to be the most difficult and interesting." This *a priori* evaluation was found to be very persistent; the subject worked in this mode throughout the entire experiment. In her report following the experiment, she noted: "It appeared to me that I had chosen the most interesting and difficult mode from the very start, and therefore I didn't want to give it up."

However, even when the field of choice was limited in this fashion, the conditions of work in this mode underwent a certain modification--change in the number of properties contained in a combination. Each time, the number of properties was chosen by the subject himself. The reports of the subjects show that this freedom of choosing the concrete conditions of work in the selected mode was very attractive to the subject, since it in a certain sense permitted him to "finely tune" the conditions of working with the computer to his own possibilities, including in relation to the dominant criteria of subjective choice of the work modes.

> Thus subject K. N. commented: "I tried to find the most difficult and the most interesting mode, except that it had to be one within my capabilities. Therefore I constantly increased the number of properties in the combination." The subject successively selected combinations of three properties (twice), four properties (four times) and five properties (once). When the experiment was halted she noted that she had "not yet reached her limit."

Let us analyze the choice of a particular quantity of properties by subjects working in "combination" mode in greater detail. A comparative analysis of the activity of subjects producing goals independently and working with the computer led to the following results. Forming P-goals during independent work (without the computer), as a rule the subjects used one or two and, much more rarely, three properties of the given object. In this case analysis of these combinations of two or three properties showed that these were extremely "biased" choices (61).

In "combination" mode the choice was random, and the number of properties was determined by the subject himself. Although the instructions did not state that the choice was random, most subjects were able to deduce this, and starting their work in "combination" mode, to begin with they chose a small number of properties (two or three)--that is, closest to the number of properties typical of independent work without the computer. An interesting change occurred subsequently as a rule. Here is a concrete example.

> Subject V. L. (in her first time with "combination" mode): "I would like to try a combination with two properties, since it would be very difficult to formulate a problem using three properties. After all, the computer will be giving me random combinations." (Her second attempt): "Now I'd like to try three properties. Only I'm afraid that the problems would end up totally insane, but that would make it interesting." (Her third attempt): "I'll try three one more time, and then perhaps I'll go on to four."

> The computer provides the following properties: "weight," "length," "thickness." Subject: "Well, this is no good. That's the way to get bored quickly. All of these properties are so closely associated that the problem simply begs itself. Of course, I'll name a few problems to raise my score, but I don't particularly care for them."

Thus a certain change occurred in her evaluation of the mode, connected with change in the system of dominant criteria for making this evaluation. In the *a priori* analysis stage the same subject rejected the "combination" mode mainly due to the random nature of the choice of properties provided by the computer ("difficult and, consequently, not very interesting"). Then while working in this mode she ceased liking "associated properties" because in this case the problems begged themselves which is also not very interesting--except that in this case we now find that the simple tasks are the ones which are not very interesting.

In our opinion the reason for this lies in the fact that in addition to the dominant criteria of mode assessment explicitly stated by the subject--ones such as difficulty or interest, there are also hidden criteria which can be revealed only on the basis of deep psychological analysis of the subjects in the experiment (in the overwhelming majority of cases, the possibility that such hidden criteria may exist is not accounted for by engineers developing automated systems, resulting in ineffective use of these systems).

Thus one such hidden criterion was associated with a subject's subjective evaluation of the productivity of his own activity (this criterion of mode choice was not named by any subject, even in response to leading questions designed to reveal such criteria). The connection between this criterion and others (explicit) is as follows. Despite the fact that activity in "combination" modes becomes significantly more complex when a large number of properties are chosen, the subject's self-evaluation of the products of his activity may rise under these conditions. For the sake of obtaining a product with a subjectively higher evaluation, the subject selects a more difficult mode, even when it is assessed to be uninteresting on the basis of "explicitly" worded criteria.

In some cases subjects offered a rather elaborate explanation of such action in the form of concrete goals and verbal evaluations.

> Thus subject S. Zh. began work in "combination" mode with a choice of three properties: "Three is best because two is not enough and four is too many, it would be difficult to think up a problem, and it is not very interesting when it is very difficult." However, the second time he asked for "combination" mode he selected five properties, commenting: "I want to tax myself. I know that the properties do not follow any sort of system and that they are difficult to combine, but still I want to try to combine all five. Of course, this would be very difficult, but then I might just end up with a really good problem, and if things do not work out right away, I can always try again."

Thus subjects consciously select conditions of working with the computer that are the farthest from the conditions of their independent work (biased choice of a small number of the object's properties), since in this case the possibilities of the computer in a sense broaden and raise their own possibilities for producing P-goals (Table 6).

Table 6. Comparative Data on Changes in the Number of Properties of the Object Used by Subjects in Their P-Goal Statements During Independent Work (Without the Computer) and During Work With the Computer in "Combination" Mode (Second Group of Subjects)

	No. of Goals in Which Following Numbers of Properties Were Used, %											
	Experiments Without the Computer				Experiments With the Computer							
Subject	1	2	3	4	1	2	3	4	5	6	7	8
1	100	0	0	0	0	0	14	56	30	0	0	0
2	80	20	0	0	0	30	24	30	16	0	0	0
3	100	0	0	0	0	20	10	40	20	10	0	0
4	100	0	0	0	0	0	25	20	30	10	10	5
5	90	10	0	0	0	0	50	20	13	10	7	0

The personal features of the subjects manifested themselves quite clearly in mode selection. Thus, using the same criterion, for example the difficulty of work in the given mode, and arriving at a similar conclusion as to which mode is the most difficult from their point of view, depending on their personality features the subjects could either select or reject the given mode on the basis of this conclusion.

We were especially interested in a criterion used in the choice of computer mode which we labeled "the possibility of acting without hints." The developers of "artificial intelligence" systems often note that the higher the "computer's intelligence" is, the more optimum and natural is the interaction between it and the individual. Our data said something slightly different. We found that in the stage of *a priori* analysis, subjects often rejected the "problem" mode--that is, the most intellectual mode of the entire set. Thus in the first experimental group 14 out of 20 subjects ranked the "problem" mode in last place during *a priori* analysis, noting in this case that they had no intention of working in this mode. Only 5 of the 14 subjects changed their opinion during the experiment--that is, they began working in this mode. But in *a posteriori* analysis three of them ranked this mode in second-to-last place. Here are the most typical examples:

> Subject L. I.: "'Problem' mode would be dictatorial, since I would have to use what the computer gives me."
>
> Subject S. Zh.: "'Problem' mode is nothing but coaching, the most brazen coaching! That's very unpleasant. I'm the person, it's the machine, and it's trying to coach me! Moreover it's coaching me not in something inconsequential but in something that I, as a person, should do better than it. I find it insulting to know that the computer can calculate better than me, though it is not performing any calculations in this instance. Of course, I'm not trying to say that it can do this better than a person, but nevertheless it all seems unpleasant somehow."

We noted earlier that the goals of action may serve as criteria of mode choice. In this connection we were considerably interested in analyzing conflicting criteria as well as conflicting goals, which were quite clearly revealed for a number of subjects.

Thus one goal--learning as much as possible from the computer--could be contradictory to the goal of working independently.

> For example, subject O. V. commented in her report: "Had my task not been to think up a problem on my own, I would very much have wanted to try out the 'problem' mode, since I was interested in what a modern computer can do in this direction. Had I chosen 'problem' mode, I would still have wanted to avoid the influence of hinting, and this might not have been easy; moreover, the smarter your computer is, the more difficult this would be to do. When I have to work with someone else's original ideas, my mind goes blank."

In this case the goal of working independently was dominant, and so the subject rejected the "problem" mode . In a number of cases however, the C-goal may turn out to be the dominant one. Here are concrete examples.

> Subject S. Zh.: "Now I would like to do something entirely different. Rather than giving the computer something original, I want to learn a little more from it, and so I'll state my own problems, but only for this purpose."

Domination of a C-goal may be temporary in this case (we made a special examination of a case of false demonstration of C-goals earlier). In a number of cases this is associated with a certain strategy selected by the subject himself.

> Subject G. T.: "'Problem' mode would be the last resort. First I need to learn as much as I can about the potentials of the computer, I must know what weapons to use against it. After all, 'problem' mode is essentially the most brazen coaching, and I want to work on my own, independently, without copying what the computer has to say; I would simply be unable to divorce myself from the computer, and that would be degrading."

It would be interesting to note that only one subject made mention of the possibility that "coaching" may occur in other modes as well; the rest of the subjects "accused" only the "problem" mode of this. Thus it may be asserted that as the computer's "intelligence" grows, difficulties associated with developing optimum modes of interaction with the computer may not decrease--on the contrary they may even increase. This would occur, in particular, because certain features and characteristics inherent to human communication may be carried over (including in altered form) to the situation of "dialogue" interaction with the computer.

An analysis of selection of computer operating modes would be incomplete without studying the dynamics of this choice in the experiment, since we would thus be able to make conclusions concerning the dynamics of the criteria, the goals and the evaluations associated with them. It was noted above that only 30 percent of all of the subjects stated in their reports that they wanted to try to work in all modes in succession, since otherwise they would not be able to choose that mode which was most suited to them. What, then, caused the other subjects to change their work mode?

One of the factors responsible for a switch to another mode was satisfaction of cognitive interest in the previous mode and arisal of interest toward other modes. Modes may also be switched as a result of an inconsistency between the *a priori* evaluation of a given mode and its *a posteriori* evaluation. A subject may also switch to a new mode because in the previous mode he found the work easy (he was successful) or, on the other hand, because work in the previous mode was hard (he was unsuccessful).

But the most interesting factors responsible for changes in mode were those associated with the subject's evaluation of the productivity of his own activity in a certain mode, based on independently formulated criteria; in this case an evaluation of both the activity itself and its concrete products was implied. Moreover evaluations pertaining to the product of activity and to the process of this product's acquisition could be conflicting. Here are a few of the most typical examples.

> During *a priori* evaluation of the modes subject O. L. commented: "The most interesting mode is 'original property,' and the least interesting are 'combination' and 'problem.' I don't even know which is worse, 'problem' mode or 'combination' mode. Both are dictatorial, and entirely uninteresting." Then the subject began working in the "original property" mode, but after two attempts with this mode, which she assessed as unsuccessful, she commented: "Yes, the properties are rather original, but what's the sense. I can't think of anything interesting to go with them, and I simply don't want to. I want to try another mode."

After this the subject began working in "combination" mode, which she had ranked second to last during *a priori* evaluation of the modes.

In a number of cases the mode choice was predetermined at the very start by the subject's evaluation of his predicted productivity.

> Thus after working in "original property" mode subject S. Zh. commented: "Yes, now I understand that despite the originality of the property, the problems may end up being unoriginal, and this is objectionable. In this sense "combination" mode would be better. I did not understand this right away. To be more accurate, I made an incorrect choice. I thought that if a property was original, then the problem would necessarily be original, but this is not so."

And so, psychological analysis of an important factor governing the effectiveness of man's interaction with a computer--selectivity in utilizing the possibilities of the computer and the subjective evaluation of the concrete forms in which these possibilities are realized--demonstrated that selection and change of modes of computer operation are processes with a complex structure. They involve *a priori* and *a posteriori* analysis of the offered modes, subjective evaluations of activity and its products in a given mode, made on the basis of independently formulated criteria, and evaluation of the possibilities of the computer itself.

We revealed the following factors influencing selectivity toward the forms of realization of the computer's possibilities: cognitive interest, subject evaluation of the complexity and successfulness of activity in the given mode, subjective evaluation of the possibilities for maintaining the leading role in goal formation. We demonstrated the conflicting nature of a number of evaluations, their interaction and the dependence of change in the evaluations of the modes themselves on different combinations of these factors and the dynamics of their development during the subject's activity in the experiment.

Moreover we demonstrated that growth in "computer intelligence" is not always directly associated with optimization of interaction between man and computer. Moreover difficulties in developing optimum forms of interaction may even increase due to the carryover of certain features and characteristics of human communication (including in modified form) to the "dialogue" situation. As a result the most "intelligent" modes may even be rejected by the users.

Comparative Analysis of the Productivity of a Subject's Activity During Independent Work and During Use of a Computer

The experimental results permit the assertion that the traditional parameters for evaluating the productivity of P-goal formulation--the total number of P-goals produced (related to the time of their production) and the percentage of acceptable variants--are clearly inadequate. Therefore we broadened the list of possible parameters by including the characteristics of both the process itself of producing P-goals (various temporal parameters for example) and its end products--P-goal statements.

The products of goal forming activity were evaluated on the basis of both qualitative criteria (revelation of which was a special objective of the research) and quantitative criteria--we calculated not only the total number of P-goals revealed by the subject but also the number of "universal" directions of the object's analysis, the number of subgoals formulated, and the number of times the subject went beyond the bounds of the object's traditional uses.

By utilizing these parameters, we were able to evaluate the productivity of the individual's activity during independent work and in "dialogue" interaction with the computer with better grounds.

When the computer participated in the work, the number of P-goals revealed in fulfillment of instruction P1 increased by an average of 152 percent, the quantity of "universal" directions of analysis increased by 60 percent, and the number of P-goals not associated with the object's traditional uses increased by 160 percent. All of this indicates a certain degree of expansion of the limits of the field of possibilities analyzed by the subject during production of P-goals.

As was noted earlier, expert methods were used in order to achieve fuller analysis of the products of goal forming activity. Both a special group of subjects who had not participated in the P-goal production experiment and the subject who produced the given P-goal--the author--served as the experts. Inclusion of the author in the group of experts made it possible to obtain interesting data concerning production of possible goals.

Many subjects noted in their reports that the better (in their point of view) the P-goals they revealed in the experiment were formulated, the more interesting the work became. Satisfaction in the work and in its results appeared. In turn, arisal of interest in the current activity had a positive influence on its productivity. In this connection we were interested in revealing which P-goal statements the authors felt to be the best, and in comparing the author's evaluation with the opinion of other subjects (experts).

Statistical treatment of the expert data showed that the author's opinion often differed significantly from the opinion of the experts. This inconsistency was elicited in particular by the influence the concrete features of P-goal production had on the subsequent evaluation applied to the goals.

Thus a large number of subjects producing goals while working with the computer in different modes were observed to exaggerate their evaluations of those goals which were hardest to formulate and those goals which permitted the subject to "invest himself" to a greater extent into their computer-assisted formulation. It would be interesting to note that quite often this process went on in the presence of conflicting evaluation criteria.

To some extent the significant increase in time required to produce goals and the remarks made by the subjects during the experiment served as indicators of the difficulty of goal formation. The desire of subjects to work as independently as possible despite referral to the computer for assistance ("avoiding hints," "using hints but contributing as much as possible to the problem on my own" and so on) could be gauged from the reports of the subjects as well as from the line of reasoning of the subjects during the experiment.

If despite difficulties and the "obstrusiveness" of the hints the subject was nevertheless able (in his opinion) to fulfill his task, the resulting P-goal statement was often "defended" by the subject against possible criticism ("This problem is not formulated very well, but it is very important," "It may be true that the problem may not look so good to an incidental observer, but it's the best I've done" and so on). As a rule such a problem was given one of the highest evaluations when ranked after the experiment; in a number of cases the decision of the subjects was accompanied by a "speech in defense" of the problem.

But in our opinion the very desire to "defend" a problem against possible criticism indicated the existence of certain conflicting evaluation criteria, the existence of doubts in the subject as to the validity of the high evaluation he offered. In this case, when the subjects described the process of such evaluation aloud, they never suggested criteria such as "difficulty of goal production" or "making my own contribution." It would be interesting to note that if after the problems were ranked the experimenter directly asked whether or not such criteria existed, many subjects gave a negative reply.

We add that in and of itself, time spent on producing goals did not correlate significantly with high goal evaluation. Thus a subject might abandon his intention of "extricating himself from a difficult situation with dignity" and formulate a problem which "would at least somehow associate the properties suggested by the computer." Such goals were given a low evaluation as a rule, though in some cases they could be given a rather high evaluation.

> During the ranking, subject O. T. commented: "Although this is a rather meaningless problem at first glance, something more could still be done with it."

Thus he essentially said that it was possible to elaborate further on a process which he had abandoned in the course of the experiment. In a number of cases a "failure" associated with production of a given problem could also be exaggerated.

> Thus a subject might note: "Strange, when I wrote this problem down it seemed to me to be rather stupid, and now I see that there is something to it."

The results permit the suggestion that there exists a certain dependence between the subjective evaluation of the difficulty of the P-goal production conditions set by the computer, the difficulties and unique features of this process in these conditions, and the subjective evaluation of the products themselves of goal forming activity.

Statistical treatment of the data obtained during initial and repeat ranking of P-goal statements revealed stable preferences on the part of the experts. Analysis of these data showed that in addition to a certain system of stable criteria applied to the products of goal forming activity, as a rule there exists a certain system of criteria formed during ranking. These criteria may be situational in nature, and they may be distinguished by significant variability in comparison with the stable criteria. Moreover variability in the definition and interpretation of the objects of ranking--that is, the P-goal statements--plays a large role in the evaluation process. The subject in a sense "gleans new content" from the objects and correspondingly changes both the criteria of their evaluation and the characteristics of value themselves.

Sometimes these factors led to significant disagreement in the opinions of individual experts (Figure 5). As a rule however, even in these cases there was evidence of rather high consistency in the opinions of the group of experts as a whole (the concordance coefficients were significant at the 5 percent level).

Out of 22 subjects performing the ranking procedure in response to instruction R1 during simultaneous ranking of goals produced independently and goals produced together with the computer, 15 showed preference for goals produced together with the computer--that is, the averaged sum of the ranks for these goals was lower than for goals produced independently. A second series of experiments was performed with instruction R2 in order to support a more-detailed analysis of the causes of such a "preference." In this series we first analyzed the criteria used to evaluate goals produced by others (the "supervisor's situation") and the subjective criteria applied to selection of a goal from a certain set of alternative goals (the "subordinate's situation"). We revealed the following two most frequently mentioned criteria in this research--problem importance and problem originality. Then we performed the ranking procedure on the basis of these two criteria.

Quantitative treatment of the expert data produced the following results: For 60 percent of the subjects in this group, the evaluations for originality of goals produced jointly with the computer were significantly higher than for the goals produced independently. For 35 percent the differences were insignificant, and the

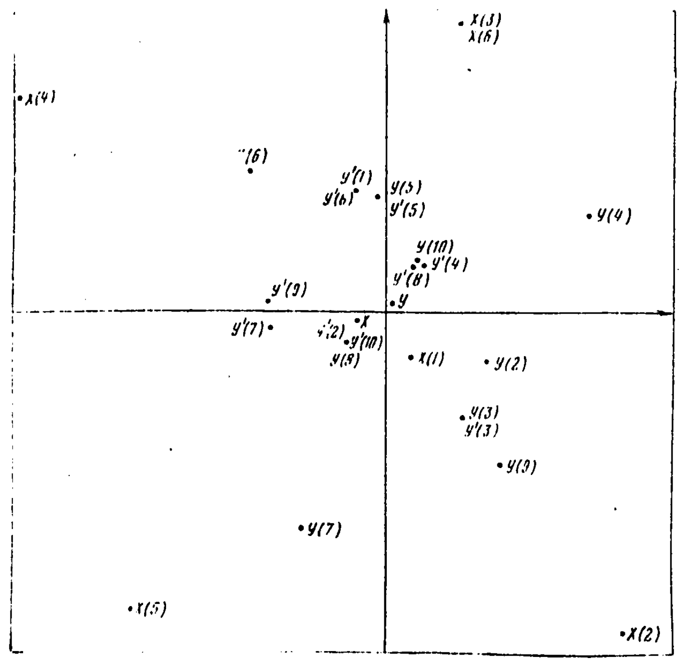


Figure 5. Ranking, by 10 Experts, of the Wordings of P-Goals Revealed by Subject O. M. During Independent Work (Without the Computer): Subject O. M. is in the expert group as number 2; $X(i)$--objects of ranking; $Y(j)$--expert with number j (involved in initial ranking); $Y'(j)$--expert with number j (involved in repeat ranking)

evaluations were lower for only 5 percent. Evaluations for importance were somewhat different: For 45 percent they were higher in the case of independent goal production, for 30 percent the differences were insignificant, and for 25 percent the evaluations for importance were lower with independent goal production than with production of goals together with the computer (Wilcoxon's two-sample shift criterion was used to evaluate the significance of the differences).

It may be noted on the basis of these data and the reports of the subjects that when goals were formulated in "dialogue" mode, most subjects managed to produce goals that were more original but less significant.

It is interesting that many subjects recognized this while producing goals in "dialogue" mode and attempted to protect the P-goal statements they produced from possible criticism.

Subject A. M.: "The idea is basically there. Right now it doesn't sound very thoughtful, and for the moment it cannot be given a high score for importance, since for the moment I can't prove this. But there is something here to think about."

Quantitative treatment of the expert data showed that the opinion of the experts and authors relative to a particular group of objects out of the total objects subjected to ranking agreed in many ways. Disagreements were mainly connected with the order in which the objects within these groups were ranked. In this analysis we were especially interested in a case where the subjective evaluation made on the basis of the originality criterion was higher for goals revealed with the assistance of the computer, and when it was higher in relation to the importance parameter for goals produced independently. Here is a specific example.

While producing P-goals independently, subject O. M. noted several times that she was having a hard time fulfilling the assignment and that "although I very much wanted to think up something original, nothing came of it."

She had to give up her attempt to fulfill instruction P2, specially oriented toward originality. Ranking her P-goal statements revealed with the computer's assistance, she assessed them as extremely original but not very important. Treatment of the expert data showed that this opinion was shared by all nine experts.

We were especially interested in the verbal portraits of the authors which the experts had to give after the ranking procedure. For this purpose P-goal statements supposedly written by different people were shown to the experts--not on cards this time, but on separate sheets. Actually, these were goals revealed by the same individual but under different conditions--independently and with the assistance of the computer. The experts were asked to state their opinion of these supposedly different authors. The expert was not informed that the author was in fact the same person. In the example we will consider here, the first sheet with the title "Subject 1" listed the goals formulated by subject O. M. [female] independently. The second sheet titled "Subject 2" listed goals revealed by the same subject working with the computer in dialogue mode. Here are concrete examples of the experts' responses.

Expert O. V.: "Subject 1 is young, and probably a girl. Very organized, logical to the extreme. Sets a goal and proceeds downward on the ladder of importance. Attached to what she knows, and relies only on it. But if I needed a 'clear thinker' for a certain job, I would not have chosen such a colleague: Perhaps he may become a worker who responds to orders reasonably well, and in any case a very conscientious worker. Subject 2 is an entirely different person, I like him very much. He stays loose, his thinking doesn't have the rigidity that mine does, for example. Perhaps not everything he wrote down is useful, and perhaps some of these thoughts are totally 'wild' at first glance, bordering on absurdity, but such ideas are needed. While subject 1's ideas left me indifferent, here I immediately encountered a number of incidental problems. I am even sorry that I can't say anything about them. You know, such a person should not be subjected to any kind of training, so that he would not get limited, so that he would not get stuck in a framework of certainty. He only needs a little push, though not right away. It is difficult to make any conclusions about his logical capabilities, and we shouldn't even try, he should be saved for those moments when he is needed. Such people are needed. I could hardly work in this way, I am a little too critical for that."

Expert L. M.: "Subject 1 is probably a good worker and administrator. He is more practical than subject 2. Obviously it would be good to get his advice on practical problems. Subject 2--well, he's an entirely different person. It would be interesting to talk with him because he could open up completely new aspects of things that have been long known. He is much more original than the first, but he is totally unpractical, like a child. If one of his ideas would require some exotic plant, it would never cross his mind that it would have to be imported all the way from Africa. In general, it would be good for these two people to work together, assuming of course that the first would not be envious of the second."

Expert S. S.: "Subject 1 is more practical, he has work experience, he knows his job, but he doesn't have any ideas. He's purely a practical worker, he can be used only for practical work with someone else's ideas. He couldn't invent gunpowder. Subject 2 on the other hand is little acquainted with practicality, he doesn't suggest important ideas, and he offers no practical solutions, but his ideas are rather unexpected. They are original, and somehow very attractive. Probably because they are so far afield of tradition. They are not very applicable from a practical point of view, but this person does have an original way of thinking. He should not be set to work on other people's ideas. If he is able to learn the job, he would find it easier to orient himself in the sea of his own ideas--people like this have many of them."

Expert P. T.: "I don't like subject 2. He does everything better than I--such ideas would simply never have entered my head. He is higher in mental development than subject 1. Subject 2 could transfer his technical knowledge even to everyday things and make them interesting. Subject 2 is probably a man. Subject 1 is in teaching or writing. Precise, probably a woman. A good worker."

Expert A. L.: "Subject 1 approaches problems more practically. Subject 2 has less substance. Subject 1 takes a more-complete approach, while subject 2 is bent on originality, though his facility with industrial production is not generally very good. He probably thinks he's a genius. I feel that he has a passion for being original. But practicality and originality must be interrelated--otherwise things would be absurd. I don't generally like such people. What would happen if all of a sudden we find out that he's not really a genius but simply likes to say off-the-wall things. Subject 1 could be relied on, probably a woman or an elderly man."

And so, the experimental data permit the hypothesis that subjects showed preference for goals produced in "dialogue" with the computer, because in this case they were in a sense able to expand their possibilities and reveal more-original goals, which was preferable to many of the subjects.

We did of course observe a certain decline in the evaluations of goals on the basis of the importance parameter concurrently with this. Therefore we included a number of supplementary instructions in the experimental method. Thus we asked the subjects to specially analyze, after the experiment, those P-goal statements which had a low evaluation on the basis of the "importance" parameter concurrently with a high evaluation based on the "originality" parameter. In this case we provided the supplementary instruction: "Try to modify these problems in such a way that they would become more important without detriment to their originality." The subjects handled this assignment relatively easy But it was significantly harder to modify the same P-goal statements in such a way as to improve their evaluation based on the "originality" parameter (some subjects would not even try to complete this assignment).

Thus we developed and implemented a variant of the expert procedure which can be used for qualitative evaluation of the products of human intellectual activity and for comparison of these products, arrived at by an individual working in "dialogue" mode with the computer and without the computer, on the basis of qualitative indicators.

By using the expert methods we were able to deepen the analysis of human intellectual activity in "dialogue" with a computer. The results of this analysis revealed additional parameters characterizing goal formation, namely the P-goal "originality" parameter and the P-goal "importance" parameter. In terms of these parameters, activity performed in dialogue with a computer is typified by higher evaluations for P-goal originality and a certain decline in relation to the importance parameter. However, under the influence of a supplementary instruction the subject could relatively easily modify P-goal statements to arrive at a higher evaluation in terms of this parameter. But at the same time it was hard to modify goals in such a way as to raise the originality evaluation.

Consequently the "dialogue" mode we developed would best be used primarily to raise the quality of goal forming processes in terms of the "originality" parameter.

Investigation of the Possibilities of Controlling Goal Formation in "Dialogue" With the Computer by Influencing Emotions and Motivations

The preliminary experiments, performed without a computer, showed that a significant number of the subjects were affected by the motive of competition with other subjects, ones whom they had predicted would participate in similar experiments. That this motive arose may be deduced from their questions and from the statements they made during the experiment, from the reports they gave following the experiment and from the particular features of their activity. After the experiment many subjects asked how others had performed in this experiment. The questions asked of the experimenter in this case often helped to reveal goals associated with this motive and those the subject formed while fulfilling the given instruction. Thus subjects usually asked about the number of properties or P-goal statements named by other participants of the experiment.

Let us now dwell on the experimental methods in which the effectiveness of intellectual activity was raised by organizing special forms of "dialogue" with the computer capable of influencing the subject's emotions and motivations. The experimental situation stimulated arisal, in the subject, of the "motive of competing with the computer" under the influence of the computer's responses. Such indirect influence on motives was more effective than instructions directly orienting the subject toward competition. Considering the limited possibilities of modern computers for analyzing messages in natural language, we used a simplified model in which we substituted the naming of possible goals of analysis of a certain object by revelation of the properties of this object. The obtained data were used to study the possibilities for optimizing the goal forming process itself.

A number of tests were performed to reveal possible differences in the use of this simplified model. Subjects participating in these tests were given instructions similar to those described below. The only difference was that they were asked to produce P-goals rather than properties. The tests were performed only in the ADS mode, in which the computer's work was simulated by the experimenter. Twenty subjects (college students) took part in the tests.

The following instruction (RS1) was transmitted to the subject via a computer linking unit (the display of an autonomous display system (ADS) or the typewriter console of the computer in cases of actual interaction with the computer): "'Object'...(the name of the object is given). Please name the properties of this object. Send a message after each property, and wait for my reply. If you wish to stop work, simply type the word 'end'."

The computer made one of the following responses to each property named by the subject: 1) I know this property; 2) I know this property, it is named often; 3) I don't know this property. Everyday objects were named in the instructions: pencil, match, chair. The order of their presentation was the same for all subjects.

The computer memory contained 120 properties for each of these objects, revealed from the results of the preliminary series of experiments described above. These were properties which were stated in one, two or three words and which could be expressed as a certain standard verbal construct with fill-in blanks: "The object (name of object)....can (one of the functional properties of the object)...." Properties named by more than 50 percent of the subjects participating in the preliminary series of experiments were placed in the "named often" category. Thus while working with the computer, each subject could compete with the participants of the preliminary series of experiments (a situation of competition between experiment participants mediated by a computer).

Analysis of the data obtained from all experiments in this series (series RS) was performed in relation to the following parameters: 1) the number of properties revealed; 2) the number of original properties; 3) instruction fulfillment time; 4) time intervals between the subject's responses; 5) refusals to continue activity; 6) the sequence of computer responses.

The line of reasoning of the subjects was recorded during the experiment itself (on tape) and following the experiment in the form of an unprompted report and as answers to questions, which will be presented below. The following served as indicators that the motive of competition with the computer arose: a) statements made by the subjects during the experiment and their emotional undertone; b) questions asked of the experimenter; c) the subject's reaction to computer responses and the dynamics of their change during the experiment; d) the subject's attitude toward lengthy series of identical responses from the computer; e) data in the subject's report.

Forty four subjects participated in the experiments on instruction RS1. These were college students, high school students in their senior years and professional computer users. Certain difficulties requiring some changes in the experimental method were revealed in the very first experiments. This was particularly true of problems associated with the subject's possibility and need for obtaining a correct response from the computer.

When an autonomous display system is employed, the possibility of obtaining a correct response is limited to a significant extent by the experimenter's own capability for simulating the work of the computer. In real interaction, meanwhile, the computer was unable to analyze lengthy messages which were written in natural language and which would not yield to standardization. We doubtlessly could have taught the subjects to word their properties in a way which would be compatible with computer analysis, but this did not seem to be a suitable approach. Besides creating the danger of indirectly coaching the subject while training him, we would also have had to exclude from the analysis those properties which could not be worded in standard fashion, and the latter are precisely the ones which are of the greatest interest to the analysis.

Another solution might have been to create "computer-experimenter-subject" interaction, in which the potentials of the experimenter would be amplified by the computer. But although this approach does appear promising in terms of subsequently developing a general method for automating the psychological experiment, it would have required a significant increase in the time intervals between the messages of the subject and the responses of the computer, which was undesirable in this experiment.

Some interesting procedures maintaining the illusion of human communication with a computer have been developed in known "dialogue" programs (ELIZA, PERRY and others) in order to "simulate" a degree of understanding which the computer naturally does not possess (27, 117, 119, 155).

Following these traditions, we developed three variants of mode RS1 described above. Whenever the wording of a property would not yield to computer analysis, in the first variant the computer produced an additional response: "Next property" (the correct response mode--RS2); in the second variant one of two responses was selected at random: "I know this property" and "I don't know this property" (mode RS3--random response); in the third variant the same responses were given in a more evasive form: "I know this property but in a somewhat different wording" or "I don't know this property, though I do know some similar ones" (mode RS4--evasive response). Thirty subjects (VUZ students) took part in experiments on these instructions.

We were especially interested in the case where a correct response could in principle be obtained from the computer, but where this was undesirable, inasmuch as it could ruin the motive of competition. One hundred twenty properties associated with each object were fed into the computer memory. Assuming that the computer necessarily provides correct responses, such a rival might be too strong for some subjects and insufficiently strong for others. In such a situation, random responses--be they even evasive responses--would be undesirable, as would their presentation in accordance with a special program--for example depending on the length of the series of previous responses subjectively perceived by the subject as unpleasant or pleasant. As the preliminary experiments showed, sharp inconsistencies in the subjective evaluations made of the computer responses by the subjects are unavoidable with this approach, which in turn results in frustration, the destruction or weakening of the motive of competition, and sometimes violation of "dialogue" interaction itself.

We hypothesized that the number of such inconsistencies could be significantly reduced by using some additional objective data which, when fed into the computer, would allow us to at least partially predict the subject's subjective assessment of certain products of his activity, and to monitor the dynamics behind development of the competition motive. As was noted earlier, the characteristics of autonomic parameters, which reflect emotional evaluations to a certain degree, were chosen as such data. To the extent we can judge from the literature, this is the first time this principle is used in the organization of a "dialogue" mode.

It stands to reason that this hypothesis could have a real basis only if we could differentiate among the corresponding autonomic changes with sufficient precision and establish their mutual relationship with some subjective evaluations of the subjects.

To test this out, we had to conduct a special series of experiments, for which purpose we supplemented the experimental method.

The autonomic parameters we recorded from all subjects fulfilling the above-described instructions S1, S2 and RS1 in ADS mode were the GSR ((Fere's) method) and pulse. The method used to record these parameters is described in detail in (25). The following times were labeled on the tape on which these parameters were recorded: 1) the moment the subject fed his message into the computer; 2) the moment the subject began typing a new message; 3) the moment message typing was terminated and, in mode RS1, an extra label; 4) the moment a response was obtained from the computer.

We analyzed the following indicators: a) appearance of significant phasal changes in autonomic reactions in relation to background values (beginning with 3 kOhms for the GSR and 15 beats per minute for pulse); b) the frequency of these changes; c) their dynamics; d) changes in autonomic reactions occurring in different stages of the subject's principal activity depending on its features. We also had to consider that the autonomic reactions may differ in sign; therefore to be able to make conclusions concerning the qualitative features of the subject's state, we used information from the subject's verbal report and his recorded thoughts during the experiment. The entire experiment was tape-recorded. When treating the experimental data, we correlated the tape recording, transcribed to a data sheet, with the GSR and pulse recording using the time labels on these recordings. The precision of this correlation--1.5 seconds--was sufficient for the purposes of our research.

In order to find the correlation between autonomic changes and some subjective evaluations, following the experiment we asked the subjects to rank all of the properties they named in order of preference (the experimenter did not offer a preference criterion).

One more modification of the RS1 method was developed in order to permit closer analysis of the concrete ties existing between anticipated emotional evaluations revealed on the basis of the objective indicators of emotional activation and their corresponding verbal predictions.

Mode RSV2: After a subject working on instruction RS1 named 12 properties (without giving up) or after he gave up, he was given the following instruction:

> "You have now acquainted yourself with the way the computer works. You probably noticed that the computer gives one of the three following responses to each property you name: 'I know this property,' 'I know this property, it is named often,' 'I don't know this property.' In your further work, try to guess the computer's response. To do so, each time you name a property you must write down the following symbols: Z--if you believe that this property is known to the computer; N--if it is not known; Ch--if the property is one which is named often."

In this case the autonomic parameters and the line of reasoning were recorded in the same way as in the previous series.

We developed a special method permitting us to graphically demonstrate one of the real possibilities for practical use of the objective indicators of emotional activation in "dialogue" programs.

Mode RSV3: As with the previous series of experiments, this series used the ADS. The computer responses were given in correspondence with data describing the subject's functional state. Experimental data obtained in the previous series showed that for a certain group of subjects (stating the response "I don't know this property" to be the most preferable), a significant emotional undertone was typical of properties which they subjectively felt to be the most original and unknown to the computer. That this was true could be determined from their line of reasoning during the experiment and from a special interview. The autonomic parameter recording tapes for these subjects revealed sharp drops in the GSR during the time interval in direct proximity to the beginning of the typing of a new message (subjectively evaluated as original) and in a number of cases just prior to feeding this message into the computer.

In correspondence with this subjective emotional evaluation (a subjective prediction revealed on the basis of the objective indicators of emotional activation), the experimenter simulated the work of the computer with the ADS, outputting computer responses according to the following system.

1. Right ("I don't know this property"), when the subjective prediction agreed with the real situation--that is, when the property was not contained within the library of properties.

2. Wrong ("I don't know this property"), when the subjective prediction did not agree with the real situation--that is, when the property was known to the computer, and when a long series of responses undesirable to the subject (more than four) were given to him prior to this point.

3. Right ("I know this property" or "I know this property, it is named often"), when the subjective prediction agreed with the real situation as well as when it did not agree with this situation but the number of previous successive responses undesirable to the subject was less than four.

Twenty-eight subjects took part in experiments with instructions RSV2 and RSV3--college students and professional computer users. After they had fulfilled the series RS instructions and written their unprompted reports, they were all asked the following questions.

1. How did you react to the computer's responses (to each response)?

2. Did your attitude change in the course of the experiment?

3. Why did you stop working (if the subject had given up during the experiment)?

4. Precisely what properties did you want to name?

5. Did this wish change during the experiment?

6. Were you always able to think them up?

7. If not, what did you do in such a ase, and why?

8. Was the number of properties you named important to vou? Why?

9. Was the quality of the properties you named important to you? Why?

10. Did you try to second-guess the computer's responses? If yes, then why did you do this?

11. Did you enjoy working with the computer? What exactly did you like, and what did you dislike?

12. Did you have any sort of emotional experiences while working with the computer? If yes, what kind, and with what were they connected?

13. If the way your "dialogue" with the computer were to be organized depended on you, how would you like to see it organized?

Discussion and Analysis of Experimental Data. The Possibility of Controlling Goal Formation in a "Dialogue" With the Computer by Influencing Motivations

We analyzed the arisal, specific features and degree of manifestation of the motive of competition with the computer. We obtained the following data: Arisal of the competition motive to one degree or another, coupled with formation of different systems of goals (Table 7), was recorded for the overwhelming majority of subjects in all experimental groups.

Table 7. Number of Subjects for Whom Arisal of the Motive of Competition With the Computer was Recorded

Group	Total No. of Subjects	No. of Subjects for Whom Arisal of the Motive of Competition With the Computer Was Recorded, %
D1 (college students)	20	80
D2 (professional computer users)	4	100
D3 (high school students)	20	70

As a rule this motive did not form right away. The specific features of its arisal and the ways and degree of its manifestation depended on a large number of intricately interrelated factors. For example the dynamics of its arisal depended significantly on: 1) the particular features of the subject's activity during performance of his experimental assignment; 2) the computer's responses and their consistency; 3) the stability of the hierarchy of motives characterizing the subject's personality; 4) the particular ways the subject analyzed the possibilities of his rival, and his attitude toward this rival.

The subjects were not told beforehand how the computer would respond to them during their work, nor were any explanations offered as to the nature of these responses. The very nature of this reaction depended significantly on the subject's evaluation of the "intellectual" possibilities of modern computers. Three basic groups of experiment participants could be distinguished on the basis of this principle.

We placed subjects who overstated the possibilities of the computer (subjects having absolute trust in the computer, viewing it as a super-rival) in the first group. Here are some concrete examples. Subjects said: "Everything that can be known about the object is in the computer. Consequently if it responds: 'I know this property,' then I am doing the right thing, and if it responds: 'I don't know this property,' I must have made some sort of mistake: Either I worded my thoughts incorrectly or the property does not fit."

Subject O. I. (group D1): "If the computer replied 'I know,' I felt that I had given it what it wanted."

Subject G. T. (group D1): "When the computer said: 'I don't know this property' I became embarrassed, because I concluded I had blurted out something stupid. I also thought that the computer would not want to work with me any more. After all, it knows everything and the work it gave me was rather easy, but I made a mistake."

Subject A. F. (group D1): "When the computer responded: 'This property is named often,' it meant that the computer understood that I had named the object's best-known characteristic. When the

> computer responded: 'I don't know this property,' I even became angry--either the computer wasn't working right or something else. After all, it knows everything about this object, or at least a great lot more than I. And later on, although the property to which the computer replied in this way seemed right to me, I was perpetually afraid that perhaps I was making a mistake and that this property really didn't fit. This is why every time I typed in a message I was very worried that it would once again reply that the property didn't fit. I mean, the computer isn't the only one that's involved. It may be smart, but it has no soul. Later on, it lets other people read my work, making me look ridiculous for giving such totally stupid answers."

> Subject G. Z. (group D3): Following the computer's first reply, "I don't know this property," the subject asked the experimenter: "What do I do when the computer doesn't know? Do I stop with the first property that doesn't fit?" Then the subject began persuading both herself and the experimenter that the property which she had named and which prompted this response from the computer did not fit."

However, despite the tendency to overstate the possibilities of the computer, which distinguished subjects in this group, the motive of competition arose in this case as well. However, it's arisal and manifestation exhibit unique features. The subjects, who were essentially competing with other participants of the experiment, viewed the computer moderating this competition as a judge and not a partner. Here is a specific example.

> Subject Ye. A. (group D1): "The computer knows everything, but it has worked with many people and therefore it knows what properties are named especially often. Therefore I wanted my response to be a valid one, but one that is not named very often. It's best when the computer replies 'I don't know this property,' since this means I came up with a reply that is more interesting than usual."

We placed subjects with a neutral reaction to the computer's responses in the second group. There were only two subjects of this sort in all of the experimental series.

> Subject A. A.: "I didn't pay any attention to the computer's responses because I couldn't understand why it was writing all of this. Maybe it needed all of this so that it could do its analysis."

> Subject M. K.: "I didn't pay attention to the computer's responses because the computer offered no explanations as to how I was to react to these responses; therefore I didn't know what I was supposed to do, and I stopped paying any attention to its responses."

The motive of competition with the computer was not recorded for subjects in this group.

We placed subjects who were more critical, than persons in the first group, of the "intellectual" possibilities of the computer in the third group. All professional computer users and a significant proportion of the subjects in the other groups fell within it. The following attitude toward the computer's responses is typical of subjects in this group: "What the computer knows about this object was fed into it by programmers and subjects participating in the experiment. If the computer replies 'I don't know,' this means that I was able to find some original property which no one had thought of yet--this is a gap in the computer's knowledge." Some subjects of this group even felt that the form of the computer's responses was generally incompetent.

> Subject A. P. (group D3): "The thing that amazed me the most was that the computer replied 'I know' and 'I don't know' as a person would. It would have been much more natural for the computer to reply 'I have information' or 'I don't have any information.' After all, the computer can't think on its own."

Also typical of subjects in this group was a diametrically opposite attitude toward computer responses in comparison with the group of subjects examined above tending to express excessive trust in the computer's knowledge.

> Subject S. R. (group D1) notes: "I felt a computer reply of 'I don't know' to be very good, to be the most pleasant. This meant that this property had not yet been named, and I was the first to do so. But when the computer replied 'I know,' this was unpleasant, while it was completely bad when the computer said 'Named often'."

As a rule the reactions of this group to the computer responses also had a greater emotional undertone than did the reactions of the other groups. One of the obvious reasons for this was that to subjects of this group, the computer became a totally real rival, and not an omniscient judge. Some even experienced a desire to explain certain things to the computer, to help it.

> Thus subject Ye. B. (group D1) notes in her report: "I didn't like it at all when the computer replied 'I know.' This was very unpleasant, and the more it knew, the more unpleasant it was for me. When the computer made its first 'I don't know' reply, I was very happy, and it took a long time for me to settle down. Then I immediately began thinking about how I could explain it to the computer better (in C-goal), so that it could understand and know this property."

Quite often, of course, such assistance was far from disinterested.

> Thus, after the computer's first "I don't know this property" response subject O. L. asked the experimenter: "Tell me, can I be certain that the computer will memorize this property and say 'I know' to others who will be participating in the experiment after me?" Later on in the experiment the subject named the same property once again. Following the computer's response, 'I know,' the subject commented with regret: "It's a pity that it couldn't remember that it was I who taught it this property."

subjects in this group sometimes structured their activities specifically so as to clarify the "intellectual" possibilities of their rival more precisely, developing a special "dialogue" strategy (elements of personification were observed in this case even among professional users).

> As an example, here is an excerpt from the report written by subject V. L. (group D2): "I always wanted to find out what the computer really knows, and by my replies I tried to get it to tell me. I also wanted to find out if the computer could learn. For example I name different pencil numbers. It replied that it didn't know. I explained to it what the numbers meant, that they indicated the hardness of the pencil lead, and then I named another number. The computer replied once again that it didn't know. This meant that it is completely stupid. Later on I wanted to find out if it could distinguish among different shades of color if I named different colors. Does the computer memory contain knowledge about a particular object, or is this some abstract object? I was able to determine all of this by naming different colors."

From this excerpt we can see a feature typical of many subjects--perpetual transitions from perceiving the computer as some mechanical device containing a certain amount of knowledge to personification of this device and to "dialogue" with it based on procedures typical of human dialogue (determination of what the computer could "feel" and "learn," whether it is "stupid" or "smart" and so on). In a number of cases the "dialogue" with the computer was accompanied by a certain emotional undertone more acceptable in human dialogue than in dialogue with a mechanical device ("I became angry with it," "It insulted me," "I will prove it to it," "I'll get back at it," "I wish it would stop laughing at me" and so on). It should be noted that such statements were also typical of professional users engaged in "dialogue" with the computer.

Thus we can deduce a certain transfer of the forms and features of human communication into new conditions--to man's interaction with the computer. However, it would be incorrect to assert that all of these phenomena are associated only with naive personification (anthropomorphization) of the computer or with a certain inertia in the spoken word, in the habit of expressing a particular thought or an emotional state in a certain verbal form. It should be considered that a "dialogue" with a computer is computer-mediated communication between a large group of people, and not simply an individual's interaction with some mechanical device. New forms and features are inherent to such computer-mediated communication.

Thus in the experiment the subjects often attempted to clarify the sort of information the computer uses as a basis for producing certain responses, "who really stands behind the computer's back," who the real rival (or rivals) is (are). This process was often evident throughout the entire experiment. Here is a specific example.

> Subject V. G. (group D2): "At first I was not familiar with the set of concepts with which the computer was able to reply. The first time it replied 'I know' I thought that there must also be a 'I don't know' reply, which should more than likely be interpreted in two ways: 1) The answer is not in the computer memory; 2) the computer was unable to understand. Therefore I tried to word my

> subsequent messages as precisely as possible, in order to be certain that I was actually naming unusual properties, and not those which the computer was aware of in principle but which it could not understand. I perceived the reply 'This property is named often' as respectful information about the other subjects--that is, the intelligence level of the average subject. But I did not think of this right away. After I did, I became disappointed. In my opinion I was just average all too often, and I didn't like this. But at the same time my interest was raised because I wanted to try to name something that the computer didn't know. I began to perceive the computer response 'I know' as 'Someone had said this before; tell me something that I don't know, and if you can't, this means that you are stupider than the computer, and it could be taught everything'."

Thus the experimental data confirmed the hypothesis that by capitalizing on the elements of computer-mediated communication and on the tendency to personify the computer, we can influence motivations in "dialogue" mode similarly as in the conditions of collective "generation of ideas." In particular we confirmed the suggestion that conditions promoting arisal of the competition motive in subjects interacting with a computer is possible. As an example, arisal of the competition motive and the subject's active inclusion in "dialogue" with the computer manifested themselves in the following:

a) in anticipatory evaluation of computer responses: "Privately I tried to guess whether or not the computer was aware of each property I named," "It seemed to me that the computer did not have this information, but nonetheless I wanted to see how it would react";

b) in attempts to reveal the "weak point" in the computer's knowledge;

c) in personification of the computer (in arisal of special C-goals associated with interaction with a rival);

d) in attempts to determine the "real rival": "I am certain that the programmer is a man. He might have omitted or forgotten something. I tried to capitalize on this, I attempted to stand in his shoes and think about what he might have omitted."

We noted earlier that all subjects participating in this series of experiments were divided into three basic groups in relation to their attitude toward the computer as a "rival" and in relation to their reactions to the computer responses (Table 8).

However, this division is not inflexible. We observe not only certain differences in the way the subjects of each of the distinguished groups interpreted the computer responses, but also certain dynamics in the way this interpretation changed in the mind of a single subject. Here are some concrete examples.

> Subject L. S.: "At first when the computer replied 'I don't know this property' I thought that I had done something wrong. Then I realized that this was not so, and I began to want to work in areas the computer didn't know."

Table 8. Effect of the Subject's Evaluation of the Computer's Possibilities on Arisal of a Motive of Rivalry With the Computer Within Him

Experimental Group	Subgroup of Subjects, %: With Overstated Evaluation of Computer's Possibilities	With Neutral Attitude Toward Computer Responses	With "Critical" Attitude Toward Computer's Possibilities
D1 (college students)	35 / 71.4*	5 / 0	60 / 91.6
D2 (professional computer users)	0 / 0	0 / 0	100 / 100
D3 (high school students)	55 / 63.6	5 / 0	40 / 86.5

*Numerator--subjects entering into competition, %.

In the following case the competition motive arises when the subject develops an understanding of the "intellectual" possibilities of the computer, which transforms from a "know-it-all" into a real "rival."

> Subject I. Z.: "I thought that the computer knew everything. But when I became certain that this was not so and that there were things that the computer did not know either, at first I was very amazed, and later on I began to like it this way very much. The work immediately became interesting."

However, even in this case of the "debunked know-it-all," many subjects continue to maintain a certain tendency to exaggerate the computer's knowledge. Thus subject V. L. commented at the beginning of her report that "the computer is rather stupid, and it doesn't know very much." She formed this conclusion on the basis of her interaction with the computer. Later on the same subject says:

> "I could not arrive at a clear idea of what 'property' meant. In each concrete case I had to find out from the computer. As an example when I gave it some 'doubtful' property and it responsed 'I know,' I felt relieved, because I was now sure that this was in fact a property, and not something else."

And so, as a result of man's interaction with a computer, as a result of the subjective reaction of a large number of subjects to the responses of the computer, the motive of competition with the computer arises. In this case this motive manifests itself much more clearly in the group having a more-critical attitude toward the "intellectual" possibilities of the computer than in the group tending to exaggerate the computer's knowledge. One of the possible explanations of this is that to subjects with a more-critical attitude, the computer becomes a real rival, while to others it is an inaccessible rival and concurrently a strict judge.

Arisal of the competition motive significantly stimulates the activity of the subject in the experiment, which is manifested in the real products of this activity--in significant growth in original properties not only as a result of an overall increase in the number of properties named but also due to a conscious, purposeful search by the subjects for "weak" points in the computer's knowledge (Table 9). It may be said that the competition motive in a sense restructures the subject's activity, as we will show below, using formation of different systems of goals in the experiment as the example. Interesting changes also occur in the autonomic indicators recorded, as will also be discussed below. However, the competition motive is not stable. During the experiment it could weaken (this is the "first achievement" effect--refusal to compete immediately after the first success, after the first favorable response from the computer), or it could grow in intensity and lead to supermotivation, which no longer stimulates but, on the contrary, negatively influences the productivity of the subject's activity; the subject may also refuse to compete due to overstatement of his rival's possibilities. Obviously all of these phenomena are also typical to one extent or another of the motive of competition with other people. However, use of a computer opens up new prospects in this direction. It becomes possible to approach the problem of controlling motivations in a computer dialogue on the basis of more-flexible, individualized selection of the rival, the role of whom may be played by the computer. In other words it becomes possible to select a rival who would permit the subject to remain in the most favorable conditions for successful development of his activity as long as possible.

Long series of identical responses from the computer served as a typical test of the arisal and manifestation of the motive of competition with the computer. In response to them, the subject could re-evaluate the intellectual possibilities of his rival, or his interest in being successful could weaken. These changes often resulted in refusal of rivalry for, in general, refusal to work with the computer any longer. Here are some concrete examples.

For convenience of presentation we will use the following symbols: Z--corresponds to the computer response "I know this property"; Ch--to the response "I know this property, it is named often"; N--"I don't know this property."

> Subject D. A. (Ch, Ch, Ch, Ch, Ch, Z, Ch, Z, given up): "I very much wanted to name properties the computer didn't know, but I understood that this would be very difficult because the computer knows quite a bit." The same subject commented in his report: "I would have wanted the computer responses to vary more. It would be O.K. for it to know something, but not too much, since either pole would take the fun out of it and make it difficult."

Changes in the particular ways the motive of competition manifested itself could also occur as a result of a long series of the same kinds of responses: We recorded violent emotional reactions and frustration caused by frequent failures in the activity of the subject.

> Subject B. I. (Ch, Ch, Ch, Z, Ch, Z, Ch, Ch): "At first I named typical properties of the object. The computer knew a little too many. Its great knowledge began to annoy me, and I was overcome by an urge to play some sort of evil trick on it, I wanted to type

Table 9. Growth in Number of Original Properties: Comparative Indicators

Subject Group	Quantity of Original Properties (in Relation to the Total Number, Revealed Through Fulfillment of Instruction RS1), Average Per Subject, % — For Subjects Entering Into Competition: With Critical Assessment of Computer's Possibilities	With Overstated Assessment of Computer's Possibilities	For Subjects Not Entering Into Competition
D1	30	12	10
D2	33.3	-	-
D3	26.7	11.4	9

out: 'How come you know so much?' Anyway I began to name things which I was certain it would not know, I began naming the most absurd properties I could come up with. If it's so smart, let it figure things out."

Subject T. I. (Ch, Ch, Ch, Z, Z, Ch, Z, Ch, Ch): "It was very easy to work in the beginning, but then I got the urge to find a property which the computer didn't know. I got this urge after a succession of "This property is named often" responses. I began rejecting those properties which could produce such a response from the computer. I got great satisfaction when the computer did not know the property I named. In some vague way, this made me more interested in working with the computer. Why, even I don't know. I generally became annoyed that the computer was saying 'I know' all too often--that is, that it was reproaching me for being the same as everyone else."

The aspiration to win "at any price" caused some subjects to make deliberate mistakes when typing the messages out, and to give confused responses, even forgetting in this case that the experimenter could be watching. Moreover many of the subjects developed an urge to "get back at the computer" (a C-goal).

Subject P. A. (group D3) notes: "Generally speaking I didn't feel any special satisfaction when the computer finally admitted that there was something it didn't know. Nevertheless I did want to get back at it, so that it would not become conceited. No matter what, man knows more, and the computer should remember this."

It is interesting to note that this urge appeared even among professional users: Subject D. Ch. (group D2): "I was irritated by the 'I know this property, it is named often' replies. I knew that this was stupid, but I wanted to get back at the computer, I couldn't control myself, I wanted to do everything I could to set the computer on its ear."

As was noted earlier, the competition motive assumed clearly pronounced forms in a number of cases. In this regard, we should make mention of the great significance the individual features of the subject have in relation to both the fact itself that the motive of competing with the computer arises and the dynamics of this competition. Thus a long series of identical computer responses caused some subjects to give up against too strong a rival, while an even larger number of identical responses created an urge in others to win at any price.

Why did the competition motive arise, and with what sort of stable hierarchy of motives typical of the subject's personality was it associated? Some relevant information could be obtained directly from the report of the subject.

> Subject B. I.: "I wanted to show my best side"; subject Z. I.: "I wanted to feel that I was smarter than the computer"; subject P. A.: "I like to be first in everything, and I had such a strong opponent here"; subject S. A.: "I wanted to experience that feeling of superiority you get when you name something the computer doesn't know, though I didn't particularly feel that this was something to gloat over"; subject K. Zh.: "What I found most interesting was to name something the computer didn't know."
>
> It would not be difficult to note that motives such as the "desire to be first" and the "desire to put oneself in a good light" assume somewhat different forms when manifested specifically in a competition with the computer: Subject T. R.: "Generally speaking I love to win, and there's special honor in winning against the computer"; subject L. S.: "Generally speaking I'm not competitive, but it would have been embarrassing to lose against the computer. This would have meant recognizing the superiority of a soulless automaton."

What sort of functions did the competition motive perform in the activity of the subject during the experiment? Some of them associated with general stimulation of activity were discussed above (as was the possible negative influence of supermotivation). However, these forms of the finctions played by a motive in human activity do not exhaust all of the possibilities.

Let us examine certain structural functions played by the competition motive--functions which manifest themselves as a significant increase in the complexity of the system of goals associated with this motive.

1. A general increase in the number of goals occurred in relation to both the entire group and each subject taken individually (D-, E- and M-goals). In experiments in which the competition motive did arise, though spontaneously (in experiments in which the computer did not provide judgmental responses), one of the principal D-goals that arose in most of the subjects was that of naming as many properties as possible. In experiments in which the computer provided judgmental responses, the goal forming process developed more broadly. As a rule subjects participating in these experiments developed an entire system of goals associated with this motive.

Table 10. Comparative Data Characterizing Growth in D- and C-Goals, %

Types of Goals	Quantity of Subjects For Whom Competition Motive Was Not Recorded	Subjects for Whom Competition Motive Was Recorded: With Critical Assessment of Computer's Possibilities	Subjects for Whom Competition Motive Was Recorded: With Overstated Assessment of Computer's Possibilities
	Basic D-Goal Alternatives		
1. Naming the largest number of properties	60	80	91
2. Naming the largest number of properties "not named often"	-	36	83
3. Naming the largest number of properties unknown to the computer	-	68	-
4. Naming at least a few properties unknown to the computer	-	54	-
5. Naming properties as quickly as possible	70	31	58
	Basic C-Goal Alternatives		
1. Beating the computer	-	90	-
2. Guessing the computer's response correctly	40	90	83
3. Working in a direction "the computer doesn't know"	-	68	-
4. Enduring the pace imposed by the computer	40	31	58
5. "Getting back" at the computer	-	68	-
6. Finding out the "weak" point in the program	-	77	-
7. Determining what the computer knows	-	77	-
8. Obtaining information about the programmer and about other subjects	-	54	-

Table 10 provides experimental data on the principal D- and C-goal alternatives. The breakdown is somewhat conditional, however, since during the experiments the subjects often combined the goals in a somewhat complex way. We can demonstrate this with a specific example.

Subject I. B. (group D1): "At first I didn't have any questions about the instructions. Everything was understandable. Later on I came to want to find out what the goal of my work was, I guess just for my own satisfaction. Two alternatives arose: 1) naming more properties in general and 2) naming more new properties (D-goal variants). At first I wanted to simply name as many properties as possible. Later on I wanted to not only name properties which the computer did not know (a D-goal) but also to anticipate its response (a C-goal)."

It was not until the sixth property that the computer replied "I don't know this property." The subject exclaimed: "Thank God, finally!" commenting about this in his report, the subject said: "I was very happy that I was finally able to think up a new property. After all, I did want to make the best impression. After this, the rivalry turned into a game. After the fifth property I decided that it would not be bad to go for quantity, but subsequently this desire passed. I decided to begin naming original properties only (substitution of D-goals)."

The following phenomenon would also be interesting to note. We performed a special series of experiments to which the following requirement was added (in distinction from instruction RS1): "Give as many properties of this object as possible." Twenty 10th-grade students participated in these experiments. The results showed that subjects for whom the competition motive became very significant often "forgot" this requirement, since it became less important to them than the desire to name properties unknown to the computer.

2. In addition to a general increase in the system of D-goals connected with the competition motive, we could also note arisal of some special goals at a lower level. These goals, which may be conditionally referred to as "substitute" goals, came to the forefront only when the main goal began to seem subjectively unattainable. Here are some concrete examples.

Subject V. A.: "At first I wanted to name original properties only, but then I decided that quantity would not be bad either. Later on I once again stumbled on an entire class of properties unknown to the computer, and I became indifferent to quantity."

Subject S. T.: "Some of the properties I named only for the sake of quantity, so as to win time. I hoped that during this time something original might once again surface."

Subject T. K.: "I wanted to name only those properties which the computer did not know. When I was unable to do so, I also named ordinary properties, just in case. I thought that if I would not be able to win in originality, I could at least come out on top in quantity."

3. Moreover we were able to reveal the "effect of first achievement of a significant D-goal" in these experiments, directly associated with the arising motive. This effect manifested itself especially clearly among those subjects who, despite significant motivation, found their possibilities for achieving their D-goal inadequate.

The subjective evaluation given to these possibilities by the subjects themselves also played a great role in this. Such subjects often gave up immediately after the first time they were able to achieve their D-goal--for example naming an original property following a rather long series of monotonous "I know" responses. If they did continue their work, however, as a rule they tried to make the experimenter aware of the changed conditions.

> Subject B. A.: "O.K. now, I've won, this competition has now turned into a game for me, and I'd like to see what else it knows"; subject I. T.: "Well, now I'm satisfied, it's responses are no longer as unpleasant to me, since there are some things that it doesn't know either. I feel that I have won."

Thus the experimental data confirmed the hypothesis, stated above, that by capitalizing on the elements of computer-mediated communication as well as on the tendency to personify the computer, we can exercise a special influence upon the individual's motivations in "dialogue" mode. In particular we confirmed the suggestion that conditions favoring arisal of a motive of competition with the computer may be created within the subjects. We demonstrated that the dynamics of this motive's formation depend significantly on the way the subject himself analyzes his rival and on the subjective attitude he develops toward him. We also noted the role of the following factors: the personal features of the subjects, the nature of their activity during experiments and the way interaction with the computer is organized (the nature and sequence of computer responses).

We distinguished three groups of subjects differing in the type of evaluation given to their rival and their attitude toward him--groups with an overstated, a neutral and a critical evaluation. We demonstrated that subjects in the "critical" group were distinguished by greater activity in their analysis of the rival's possibilities and by a more clearly expressed emotional reaction to the computer's responses; their motive of competition with the computer manifested itself most clearly in them as well. In this case, even though the evaluations they gave were critical, even this group exhibited a tendency to personify the computer; as a rule this had a positive influence on the subject's activity in the experiment.

The obtained data demonstrated that arisal of a motive of competition with the computer caused a significant increase in the number of variants in which the experimental task was completed in relation to the "originality" parameter. This was explained not only by the stimulatory function of the motive but also by the subject's assumption of the tactic of deliberately, purposefully seeking the "weak points" in the computer's knowledge. The structuring influence of the motive, which revealed itself in the significant growth of the complexity of the system of D-, C- and E-goals--expressed as a general increase in the number of goals, growth in the complexity of their interrelationship and arisal of substitute goals--was a manifestation of this tactic's application. The hierarchical relationships between C- and D-goals changed as well.

The Possibility of Accounting for the Functional State of an Individual in Dialogue Mode

If we are to utilize objective data describing the functional state of an individual working in "dialogue" mode, we would have to clearly differentiate these data (inasmuch as autonomic parameters are polyfunctional as a rule). In this connection we stated the hypothesis that it would be possible to use the mechanisms of motivation to distinguish autonomic parameters that are significant, from the standpoint of exercising certain controlling influences, from those that are insignificant. To test this hypothesis, we had to comparatively analyze experimental series offering different conditions for arisal of the competition motive.

Series S1

For most subjects fulfilling instruction S1 (naming the properties of the given object without regard to originality), significant autonomic shifts corresponded to mistakes in typing the messages (though prior to the experiment they were told that they could ignore mistakes). Moreover significant autonomic changes also appeared at the end of the experiment even in the absence of mistakes in typing the messages. It may be hypothesized that this is associated with difficulties in thinking up new properties. This hypothesis was confirmed by an analysis of what the subjects said during the experiment and in their reports. Thus many subjects commented that they wanted to complete the experimental assignment as best as they could. Under the influence of an instruction given during the experiment, they formed a goal--that of naming as many properties as possible. It was at the moment that thinking up new properties became difficult--that is, when the real possibilities came into a certain conflict with the set goal--that we observed these autonomic changes.

In order to permit analysis of the relationship between verbal-logical evaluations of the end product of activity and the purely emotional evaluations made of the process of acquiring these products, following the experiment we asked the subjects to rank all of the properties they named in order of preference. We should note that the emotional evaluations were analyzed mainly in the course of the subject's activity in fulfillment of the instructions, while verbal-logical evaluations, which had to do with the products of activity, were analyzed after this instruction was fulfilled--during ranking.

The experimental data showed that a complex mutual relationship exists between the motivational factors, the goal and the verbal-logical and emotional evaluations. As was noted earlier, the desire to "complete the assignment as best as possible" caused a sizeable majority of the subjects working on instruction S1 to distinguish the dominant characteristics of the goal--"naming as many properties as possible," in relation to which the requirement "describe this object as clearly as possible" served as a limitation, since the properties were often directly associated only with the traditional uses of the objects, thus significantly constricting the area within which the properties were sought.

This requirement was not written in the text of instruction S1. However, as the experimental data showed, most subjects participating in this series did in fact supplement their assignment in this way. During the ranking process, moreover, this requirement, which was independently formulated by the subjects, was often the key to the order of preference they expressed. Autonomic changes, meanwhile, corresponded in this case with the principal characteristic of the goal--that is, with the number of named properties, and owing to this they were inconsistent with the ranking evaluations. The most clearly expressed autonomic shifts were observed either at the end of the experiment, when naming new properties became difficult and the level of motivation was still sufficiently high, or in the case where the subject was able to reveal a property introducing him to an entire class of properties, to a new direction.

> Thus maximum autonomic change in subject D. A. corresponded to the property "brittle" (the object was a pencil). He stated in his report: "I became very happy on recalling this property, since now a significant reserve of properties immediately appeared before me."

Such an emotional evaluation was often so significant that in a number of cases the subject gave a high rank mainly to such a property, even though this contradicted the consciously formulated verbal criterion that "those properties which describe the given object most clearly are preferred."

The special goal of naming original properties arose only among a few subjects in this series; moreover this goal was typified by instability, and as a rule the subject found it easy to abandon it. Here is a concrete example.

> Subject M. A.: "I wanted to think up some original property, but I quickly abandoned this idea because the object was a little too common, and I decided that there could be nothing original about it."

Such periodically arising unstable goals influenced the structure of emotional evaluations; sharp phasal changes in reactions, in relation to the background, often corresponded to these evaluations on the recordings of the autonomic parameters.

Thus autonomic shifts recorded in the subjects during their fulfillment of instruction S1 are hard to differentiate. The difficulties are associated with the impossibility of monitoring the changes in motivational factors, the dynamics of the goals and their dynamic characteristics. Thus in this series, interaction of the components of the "motive-goal-emotional evaluation" system permitted simultaneous operation of several evaluation criteria of identical importance (realized and unrealized). The activity of the subject is guided by a certain dynamically variable system of goals and sets subordinated to emotional evaluations. The hierarchical organization of this system is essentially what determines the hierarchy of the emotional evaluations; various characteristics of the goals (recognized criteria) and sets (unrecognized criteria) could serve as the criteria in this case. When several goals and sets are present at the same hierarchical level, the emotional evaluations associated with them are hard to differentiate. Formation of this system depends on a large number of psychological factors, motivational ones primarily.

Certain difficulties in controlling this process should be noted. Thus attempts at preventing, by means of special verbal instructions, arisal of goals, sets and emotional evaluations that are undesirable from the standpoint of the objectives of the experimental research often fail to produce the needed effects.

For example despite the experimenter's directions to pay no attention to mistakes in typing the messages or to the work pace, autonomic changes corresponding to mistakes and to hunting for the needed letters on the keyboard of the display were often clearly pronounced, and sometimes their amplitude significantly exceeded the autonomic changes of interest to us--those corresponding to revelation of the object's properties. All of this made differentiation of such shifts extremely difficult.

Series S2

The pattern was somewhat different for instruction S2, which was specifically oriented at naming original properties of the object. First of all we observed a certain correlation between autonomic shifts corresponding to those properties which were the most original from the point of view of the subjects, and their verbal-logical evaluation. Thus the ranks of the first three properties ranked by 55 percent of the subjects correlated significantly with the maximum amplitudes of autonomic shifts recorded during revelation of these properties. Second, while in relation to instruction S1 it was difficult to distinguish autonomic shifts recorded while the subject was thinking up properties from autonomic shifts observed when the subject made mistakes in typing the messages (when he was hunting for a needed letter and so on), these differences manifested themselves more distinctly during fulfillment of instruction S2.

Thus while the autonomic shift corresponding to named properties and typing mistakes varied from 3 to 7 kOhms for instruction S1, with instruction S2 changes occurred in both the amplitudes of the recorded parameters and their relationships. In series S2, autonomic shifts corresponding in time to printing mistakes usually did not exceed 3-4 kOhms (that is, they were less than in series S1). At the same time autonomic shifts corresponding to named properties (ones which were original from the subject's point of view) increased to 10-12 kOhms.

The experimental data show that when the goal of activity changes (when the subject goes on from instruction S1 to instruction S2), certain structural changes occur in this activity, particularly in the structure of emotional evaluations preceding the final verbal-logical evaluation of the products of activity. Both instructions imparted a certain direction to development of the subjective criteria used by the subjects for emotional evaluation of the products of their activity in the experiment. However while in series S1 this criterion was mainly quantitative and it appeared in the instruction in the form of the requirement to "give as many properties as possible," in series S2 it acquired qualitative definition and it was associated with the desire to provide the largest possible number of not just any properties but original ones only. In both cases the maximum autonomic shifts characterizing the degree of emotional activation corresponded with the most significant moments from the standpoint of the subject's successfulness in reaching his adopted goal. Thus maximum autonomic shifts were noted when the subject experienced the greatest difficulties in pursuit of his goal (for example at the end of the experiment, when thinking up new, and all the more so original properties, became difficult) or when the activity's successfulness reached its peak (in series 1 when properties opening up a new direction or a class of new properties were revealed to the subject, and in series 2 when the most original properties were revealed).

The results show that an instruction can regulate arisal of some forms of emotional evaluations. As was noted, however, goals, sets and emotional evaluations that may also be undesirable from the standpoint of the analysis objectives may also arise within the subject, which should be accounted for in the analysis. We were able to prevent the appearance of undesirable factors to a certain extent in series S2. This was the main difference between series S1 and S2. The experimental data permit the assumption that the reason for this lay mainly in the qualitative differences in the motives of activity in the two cases, and in the associated changes in the type of "motive-goal" relationships. In series S2, a goal of the highest order, one serving as a motive, acquired new characteristics, in turn transforming all other structural levels of the subject's evolving system of goals.

While in series S1 the subject wanted to complete the experimental assignment as best as possible and his system of goals reflected this ("giving as many properties as possible," "working carefully," "quickly" and "without mistakes"), in series S2 the subjects often associated the instruction they were given with attempts at testing their mental capacity, which stimulated maximum intensity in their activity (76). As a result the goal of naming original properties, and its different variants (offering "at least a few original properties," "giving as many original properties as possible," and so on), occupied a more-stable, dominant position in the subject's evolving system of goals. Correspondingly, the emotional evaluations underwent structural reorganization as well. The autonomic shifts corresponding to the named properties, the amplitude characteristics of which depended significantly on the subjective evaluation given to the originality of these properties, were more clearly expressed in comparison with shifts corresponding to message typing mistakes and to hunting for letters on the keyboard. Moreover the data permit the assertion that the degree to which autonomic shifts are expressed depends not only on qualitative but also on quantitative characteristics of motivational factors. Thus in series S2, in which the strongest motive arose, the amplitudes of the autonomic shifts were greater than in series S1. From our point of view, now that we have revealed this relationship between the strength of amotive and the expressiveness of the objective parameters of emotional activation, we can approach the important problem of developing objective methods by which to evaluate the quantitative characteristics of motivational factors.

And so, the experimental data confirmed the hypothesis that the concrete mechanisms of motivations can be used to separate autonomic parameters that are significant from the point of view of the goals of the analysis from those which are insignificant. However, it is precisely with the close correlation existing between motives and the structure of emotional evaluations that the main difficulty in implementing this approach is associated. The results indicate that as soon as a motive weakened (as soon as "saturation" occurred), it became difficult to differentiate the autonomic shifts.

Thus we find that we must not only create a sufficiently high level of motivation, but we must also maintain it over a certain amount of time. It was important for our purposes to establish the possibility of doing so in a situation of dialogue interaction between man and computer. Consequently we conducted a special series of experiments in which we created conditions promoting arisal of a motive of competition with the computer in the subjects.

Series RS

As we demonstrated above, many subjects working with the computer in this series developed a motive of competition with the computer. In this case significant autonomic shifts corresponded in time both to the naming of individual properties and to concrete types of reactions of the subjects to the computer's responses (this was emotional activation corresponding to anticipation of a response from the computer and to its subjective evaluation).

After acquainting themselves with the assortment of computer responses in the experiment, as a rule the subjects began showing a preference for one of the possible responses, striving to name precisely those properties which would ensure a preferred response from the computer. This change in goals had a direct effect on the content of messages fed into the computer. The reports written by the subjects showed that when they were in a situation of competition with the computer, they interpreted its responses subjectively as a "reward" (the most favorable response) or a "punishment" (the unfavorable response). Anticipation of the response was associated with the subjective prediction made by the subject as to possible success or failure (anticipation of "reward" or "punishment"), while the reaction to the response was associated with his subjective evaluation of the "reward" or "punishment." These features of anticipation and of the reactions the subjects exhibited to the corresponding computer responses--features which were also reflected by certain changes in objective autonomic parameters--were unique indicators of the arisal itself of the motive of competition, and of its dynamics during the experiment.

Comparison of the GSR and pulse recordings made from subjects entering into competition with the computer and from subjects who did not do so permitted us to assert the following differences. The GSR's of all subjects were typified by a drop in skin resistance immediately after a message was fed into the computer and when messages were printed out by the computer (in the moments of anticipation of the response and the reaction to it). However, while the drop in the GSR curve of subjects competing with the computer typically increased in amplitude from 3 kOhms to 7-20 kOhms at the moment a new goal of activity directly associated with the competition motive was adopted (the moment the subjects entered into computer-mediated competition with the other participants of the experiment), this drop in skin resistance did not exceed 3 kOhms throughout the experiment for subjects who did not develop the competition motive. Thus arisal of a strong motive led to greater expressiveness (in terms of amplitude) of certain autonomic shifts corresponding to emotional evaluations of those stages of the activity which are most significant in a competitive setting. The computer responses come to stand for "reward" and "punishment," and the autonomic reactions associated with these responses become more evident within the structure of emotional evaluations.

The subject's attitude toward a response most favorable to him changed especially clearly during the experiment when this computer response was "I don't know this property" (assuming that the subject did enter into competition with the computer). To the extent that we can judge from the reports written by the subjects and from their oral statements made during the experiment, in this case the gradual growth in the amplitude of autonomic shifts corresponding to anticipation of a "reward" and to the reaction to it could be associated with development of the competition motive. A decrease in the amplitude of the corresponding shifts, meanwhile, coincided in the overwhelming majority of cases with gradual extinction of the subject's interest in competition of this sort (this was followed either by rejection of competition or by a "saturation" situation).

An interesting change occurred in the attitude toward the most unfavorable response; this change manifested itself especially clearly in relation to long series of such responses. In these cases the curve describing change in the corresponding autonomic shifts was observed to have two shapes: a) "exponential"--continual growth in autonomic shifts that could terminate with violent emotional outbursts, and sometimes by the subject's refusal to work with the computer (subject S.A.: "That's all, I quit, the computer's making a special effort to make me look ridiculous"); b) "bell-shaped"--gradual or sharp growth in autonomic shifts followed by their extinction, often corresponding to a refusal to compete.

The experimental results showed that the concrete shape of these curves depends on the length of the corresponding series of responses unfavorable to the subject, on the individual features of the subject, and on a number of other factors. A specific example of changes occurring in autonomic shifts during "dialogue" with a computer is given in Table 11.

Table 11. Change in Autonomic Shifts Depending on Computer Responses

Computer Response No.	Computer Response	Autonomic Shift, kOhms: Preceding Response: Skin Resistance	Preceding Response: GSR	After Response: GSR	Statements Recorded During Experiment (Following Response)	Report Data
2	Z	34	5	10		
3	Z	34	8	8	What kind of property does it want? An unusual one?	I very much wanted to give a property which the computer did not know
4	Ch	31	5	8	This is bad, very bad	
5	Z	31	3	5	Ye-es	I decided that the computer knew a little too much
6	N	28	about 3	12	All right! It doesn't know	
7	N	27	5	14	Doesn't like it!	

It would also be interesting to note that in a number of cases autonomic parameters served the same purpose as oral statements made during the experiment and some contradictions in the reports written by the subjects--they reflected attempts by the subject to advertise false goals and false verbal evaluations. Thus subject B. I. noted in his report that after the computer's first "I don't know this property" response he "lost interest in the work," because he was "already satisfied with his victory," and that from then on, he worked "insincerely, with no interest at all in the computer responses." However, the autonomic shifts corresponding to "I don't know this property" computer responses continued to grow.

Thus the data showed that change in some motivational factors during man-computer "dialogue" (development of the competition motive, arisal of "saturation" and "supermotivation" situations and so on) could be monitored to a certain degree by the objective indicators we revealed. We were especially interested in studying the possibilities for revealing those autonomic parameters which would correspond to some qualitative unformalizable characteristics of properties of the object revealed by the subject, since this would permit us to tackle the "computer empathy" problem.

Certain changes in autonomic shifts also accompany the naming of properties of objects by a subject in competition with the computer. A correspondence between autonomic shifts and certain subjective evaluations of named properties was most clearly expressed in the group of subjects to whom the motive of competition with the computer was especially significant. The computer response preferred by all subjects of this group was "I don't know this property." In this case emotional activation was obviously associated with the subject's anticipatory evaluations of the computer responses, both emotional and verbal. Thus maximum autonomic shifts corresponded to those properties which, from the subject's standpoint, were unknown to the computer and which were in this sense "original." This coincided on the time-correlated GSR readout with sharp phasal drops in skin resistance during the time interval immediately before the subject began typing out these properties, and sometimes at the moment the subject fed the message into the computer (when the subject reread what he had written). Thus a real possibility arose for correcting computer responses depending on anticipatory acquisition of data on changes in autonomic parameters (a possibility for achieving high agreement between the subject's own evaluation and a subsequent evaluation by a "disinterested party").

Moreover autonomic shifts corresponding to properties which the subject subjectively evaluated as "original" revealed themselves much more clearly in the structure of emotional evaluations in this series than in series S1 and S2. When the competition motive began to manifest itself in clearly expressed form in the subjects, message typing mistakes and times of hunting for needed letters on the typewriter keyboard ceased to be accompanied by significant autonomic changes in a large number of cases (the decrease in skin resistance could remain below 1 kOhm, and be significantly different from shifts corresponding to an emotional evaluation of properties). Were they even to appear, in the overwhelming majority of cases significant autonomic shifts corresponding to mistakes and to hunting for letters did so only in the time interval associated with typing the most original (subjectively evaluated) properties, and thus rather than hindering they facilitated revelation of these properties during analysis of the experimental data. Concrete examples illustrating this premise are shown in Figure 6.

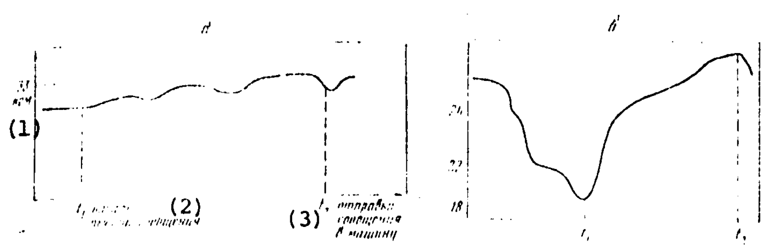


Figure 6. Subject Ch. I. Moment of Time Corresponding to Typing a Property Subjectively Evaluated as "Unoriginal" (*a*) and "Original" (*b*)

Key:
1. kOhms
2. Message typing begins
3. Message fed into computer

As in the previous series, we were especially interested in studying arisal of various new goals that were independent of the instruction provided, and their influence on differentiation of autonomic shifts. Thus during the experiments many subjects adopted the special goal of "guessing what the computer response would be"; this goal was not a requirement of the instruction. We were interested in the influence this goal had on the structure of emotional evaluations, especially in situations in which this goal could possibly assume a dominant position. For this purpose we conducted a series of experiments with instruction RSV2. After the subject named his first twelve properties, he was given the special instruction of "guessing what the computer response would be." These experiments made it possible to analyze in detail the concrete relationships existing between anticipatory emotional evaluations, revealed on the basis of objective indicators of emotional activation, and the verbal predictions corresponding to them.

The experimental data showed that for 80 percent of the subjects, the goal of "guessing what the computer response would be" arose before they were instructed to do so (as determined from the reports written by the subjects and from an analysis of their line of reasoning during the experiment). However, many of the subjects noted in this case that this was "not their main goal," since "the main thing was to name properties (give as many original properties as possible, and so on)."

An analysis of the autonomic parameter recordings showed that arisal of "incidental" goals of this sort was not a significant obstacle to differentiating autonomic shifts in this experimental situation, while in a number of cases it even facilitated such differentiation by intensifying the corresponding autonomic reactions (from our point of view this was a unique demonstration of the well known dominant principle).

Despite this, however, we do need to note certain difficulties in analyzing the obtained experimental data connected with the significant complexity of the processes we were studying. We can demonstrate this with concrete examples. A certain proportion of the inconsistencies we recorded between emotional evaluations and subsequent verbal evaluations was associated with unique "strategies" adopted by the subjects, revelation of which required special analysis. In a number of cases for example, where changes in autonomic parameters indicated that a certain property should be characterized as "original" (this would be an emotional evaluation), the subject awarded a "Z" or even a "Ch" to it. This was often associated with a desire to "win in one way or another": Either the property would be unknown to the computer ("original"), meaning that this win would compensate for the loss represented by a wrong guess, or the property would be known to the computer, meaning that the loss would be overshadowed by the win chalked up to guessing. This hypothesis was confirmed not only by data in the reports written by the subjects (as a rule by certain contradictions existing in them, and not at all by "honest confessions" volunteered by the subjects themselves in regard to such "strategies"), but also by a number of other indicators. Thus when a property was not known to the computer the emotional reaction to the loss in guessing was not negative, as would be expected in such a case, but positive: The subject smiled, he made statements such as "good," "finally" and so on.

For example after receiving the instruction "Guess what the computer response would be," subject L. Ye. comments: "Well, at last I have a specific goal, now I know what I have to do." In his report, he

> writes: "The main thing for me after the additional instruction was to guess what the computer's response would be. It was simplest of all to do this with original properties, since it is much harder to guess 'I know' and 'named often' responses correctly."

Thus the subject attempted to logically justify his desire to name only original properties, failing to note that by doing so, he contradicted a desire he himself stated in his report--"selecting the most difficult conditions for the computer game." After the additional instruction was provided, this subject revealed an increase in autonomic shifts corresponding to revelation of "original" properties and in autonomic shifts corresponding to anticipation of a "I don't know this property" response from the computer and the reaction to it. However, it was hard to attribute such changes simply to a "win" in guessing the computer's responses, since in these situations we recorded subjects saying things such as: "Got you that time, you don't know much yourself either," and so on. All of this permitted the hypothesis that in the new "computer game" conditions the competition motive and the former goal associated with it, orienting the subject toward naming original properties, not only did not lose their significance, but in a certain sense even "grew stronger" due to the arisal of additional goals. Moreover in this case the subject gained the possibility of using these additional goals to mask others significant to him, allowing him to reduce the unpleasant influence of losses.

Similar data obtained with other subjects permit the hypothesis that motivational factors may be indirectly controlled in this manner by changing the modes of interaction through changes in the appropriate instructions. However, control of motivational factors through more-flexible variation of computer responses in one interaction mode appears no less promising to us.

We recall that in experiments involving the naming of the properties of an object, not to mention experiments involving problem formulation, in a large number of cases it was impossible for the computer to respond correctly when asked whether or not it knew a given property. This is explained by the fact that at the present level of development of computer technology, computers are still unable to analyze messages written in natural language sufficiently well. This is why the additional computer message "Next property" was introduced in series RS2. This message was printed out when a particular property would not yield to computer analysis. The experimental data showed that in comparison with more-concrete responses, this one did not have sufficient motivational force for many subjects, since it did not provide the necessary information on the "opponent" and on the evaluation given to the successfulness of the subject's activity in the experiment, meaning that a motive to compete with the computer that had arisen previously could break down.

Experimental series RS3 and RS4, in which the computer printed out random unobjective responses ("evasive" in series RS4 and concrete in series RS3) when it was impossible to formally analyze properties produced by the subject, showed that the randomness of printing out such evaluations could also result in an inconsistency in functions between man and computer, and in breakdown of the competition motive that had arisen. Thus subjects said in the experiment: "The computer is responding randomly, and that's not interesting"; "Something must be wrong, since it can't be that the computer knows an original property but doesn't know the simplest ones" and so on. Especially clear emotional outbursts accompanied situations in which the self-evaluations disagreed sharply with the computer responses. Here are some concrete examples.

Subject N. A.: "I refuse to work like this. The computer has probably broken down. I just gave it a very original property, and it replied 'I know'; then I deliberately gave it the simplest possible property, one which it had to know, and it replied 'I don't know'."

Subject V. V.: "Your computer's just fooling around, making a mess of things while at the same time giving the appearance that it's answering correctly. I don't like working this way."

Thus the limited possibilities for computer analysis of messages written in natural language and of the computer's communicative functions caused breakdown of interaction modes that worked well for the subject.

In addition to cases in which the computer was unable to provide an objectively correct response, moments in which such a response was undesirable were no less important. Thus the experiments showed that long series of identical responses that are especially unpleasant to subjects could also break down an existing motive to compete with the computer; such breakdown could occur, for example, because the "opponent" is found to be too strong.

And so we revealed two factors: a) the length of the series of identical computer responses; b) consistency between the self-evaluation and the computer response. We hypothesized that changes in these factors occurring in "dialogue" mode could have certain controlling influences on the motivations of subjects interacting with the computer.

Data obtained from a number of experiments in this series allowed us to formulate specific requirements on control of these two factors:

a) monitoring the influence of a long series of identical responses on the activity of a concrete subject during an experiment, using for this purpose the changes in autonomic parameters corresponding to "anticipation" and "reaction to computer response" which, as the experiments showed, permit us to make certain conclusions concerning the arisal and change of the motive to compete with the computer;

b) preventing arisal of such long series and possibly resulting sharp disagreements between self-evaluations and computer responses, using a number of the revealed characteristics of changes in autonomic parameters for this purpose;

c) monitoring change in autonomic shifts corresponding to "anticipation" and "reaction to computer response," in the situation where the computer response "reinforces" the subjective evaluation, the nature of which was determined from an analysis of the objective indicators of emotional activation. This would allow us to make certain conclusions as to the possibility of exerting "reverse influences" on the motivation level through the use of some characteristics in the structure of emotional evaluations.

We had already noted earlier that subjects working in competition with the computer began second-guessing the computer's possible responses, as manifested not only in their statements but also by certain changes in autonomic parameters. We used these results to support the subject's motive to compete with the computer by correcting the computer responses before they were printed out. In mode RSV3, developed for this purpose, the responses of the computer were printed out following analysis of both verbal and nonverbal information (see the description of this series in our discussion of the methods).

The experimental data confirmed the stated hypotheses and demonstrated that by accounting for certain information concerning the functional state of the subject in "dialogue" mode, we were able to cause the following changes in his activity.

1. Refusals to work with the computer, resulting in previous series due to sharp disagreement between subjective evaluations and the computer's subsequent responses, disappeared.

2. Motivation maintained a positive impact for a longer period of time (the motive to compete with the computer arose more frequently and broke down more rarely).

3. The overall emotional attitude toward the activity was positive.

Thus by utilizing data describing the subject's emotional state, we were able to carry our analysis of the functions of the motives in the structure of the subject's intellectual activity further. We found that under the influence of an arising competition motive, there occurred a certain redistribution in the structure of emotional evaluations, which now became more expressive and, therefore, more easily distinguishable, and which began to show more frequent consistency with the objectively meaningful factors of the experimental situation. These results provide the grounds for the assertion that despite the psychological ambiguity of autonomic parameters, they may be used to optimize the "dialogue" mode. More specifically, they may be used to create consistency between computer evaluations and the concrete subjective evaluations of the products of activity on the basis of the "originality" parameter, or to simulate such consistency when the possibilities of computer analysis are limited; by doing the latter, we are able to prevent disorganization of the activity of subjects participating in dialogue interaction.

It was demonstrated that in a number of cases autonomic parameters are indicators of certain changes in motivational factors, and that they may reveal attempts by subjects to "demonstrate" false goals and false verbal evaluations of the products of activity. The real possibilities for exerting controlling influences on human motivations in a "dialogue" with a computer by utilizing changes in autonomic parameters were demonstrated. This makes further analysis of goal forming processes and more-flexible control over goal formation possible.

We should also note that the results of the control series of experiments (in which the subjects produced P-goals) were basically consistent with the data of the principal series, described above (in which formulation of P-goals was substituted by one of the components of this process--revelation of the object's properties). The main difference was that in the control series, sharp autonomic shifts that corresponded to the moment the subject typed "key" words in a P-goal statement could often be revealed on the autonomic parameter recordings.

These experiments revealed the real possibilities of using a computer to control the unformalizable process of goal formation. We developed special control procedures based on utilizing different variants of supplementary assistance to subjects, on encouragement of computer-mediated competition between participants of the experiment, and on use of autonomic indicators of the emotional state of the subject to control goal formation. Despite the extremely limited number of formalizable components of goal formation that could be delegated to the computer, these procedures make it possible not only to increase the total number of possible goals that could be produced, but also to significantly raise their originality in comparison with the products of independent activity (of subjects working without the computer). Different variants of the use of a computer to control production of possible goals were compared.

Production of possible goals by subjects working independently and in response to computer control of goal formation were studied. Certain factors keeping the subjects from realizing their potentials in independent production of P-goals were revealed (in particular, limitations associated with the concrete type of goal formation, with formation of a "rigid" hierarchy of universal goals and so on). Data were obtained indicating that P-goal production is selective, and that subjects exhibit selectivity in using the properties of an object and their combinations in the statements of possible goals of analyzing this object. It was for the purpose of weakening the negative influence of these factors, ones which inhibit goal formation, that we developed special "dialogue" modes. Procedures in the computer programs providing additional assistance to subjects are based on the use of randomly generated characteristics of the object (ones having different probabilities of being realized) and their combinations, as well as of algorithms for transforming revealed characteristics into P-goal statements.

It was demonstrated that in computer "dialogue," a number of features of interaction between man and computer directly influence goal formation, to include ones such as: a) the communication mode (the content of messages, the rhythm and the freedom of choice of interaction modes); b) the possibility for dividing responsibility in "dialogue" mode; c) "personification of the computer."

We classified the following as the most important factors.

1. The subject's development of the need itself for working together with the computer and the associated need for certain forms of communication with it. The possibility of forming cognitive needs facilitating the subject's communication with the computer by specially organizing his activity with and without the use of a computer was demonstrated. A special case of cognitive needs which were associated with the subject's own evaluation of his activity and which took a specific form in computer "dialogue" as the need for "computer" evaluations of the results of the subject's activity was revealed.

2. The subject's selective attitude toward using the possibilities offered to him in computer "dialogue," manifested in particular as the subject's selection of particular modes of interaction with the computer (a "free choice" of modes situation). The experimental data showed that selection and change of modes in which to work with the computer depend on a large number of factors such as cognitive interest, the subjective evaluation of the difficulty and successfulness of work in the given mode and so on. Concrete combinations of these factors and the particular features of their change during the experiment go a long way to define the effectiveness of goal forming activity.

The obtained experimental data confirm our hypothesis that controlling influences may be exerted upon the motivations of an individual engaged in "dialogue" interaction with the computer.

This work analyzed the arisal, features and degree of manifestation of the motive to compete with the computer depending on the following factors: the personality features of the subjects, their activity during the experiment and a certain type of organization of interaction with the computer (the nature and sequence of computer responses).

Three groups of subjects differing in the way their "rival" is evaluated and in the attitude expressed toward him are distinguished: 1) subjects with a "critical evaluation"; 2) subjects with an "overstated evaluation"; 3) subjects with a "neutral evaluation." Subjects in the "critical group" were distinguished by the greatest effort to analyze the possibilities of their "rival," by a greater emotional reaction to the computer responses and by the clearest expression of the motive to compete with the computer. Despite the fact that the evaluations of these subjects were critical, as with the other two groups this group exhibited a certain tendency to personify the computer, which as a rule had a positive influence on the subject's activity in the experiment. These data are of special interest for the following considerations.

First, it should not be surmised that a person always competes more readily with a computer with "intelligence" scored sufficiently high by him. Thus the competition motive manifested itself much more clearly in the group with the "critical evaluation" than in the group with the "overstated evaluation."

Second, the "personification phenomenon" is not a direct consequence of an uncritical attitude of the subjects toward the possibilities of the computer (that is, naive "anthropomorphization" of an automaton due to insufficient knowledge of the principles of its operation), obviously being instead a much more complex entity associated with "transfer" of certain features and forms specific to human communication to "dialogue" interaction with the computer (there are grounds for suggesting that different levels of such transfer exist).

The experimental data showed that arisal of the motive to compete with the computer led to a significant increase in the variants of the solutions to the experimental problem in regard to the "originality" parameter. This can be explained not only by the stimulatory function of the motive but also by deliberate, purposeful exploration of the computer's knowledge for "weak points" by the subject. Use of this tactic had a structuring influence on the motive. This influence also manifested itself in significant growth in the complexity of the forming system of D-goals, C-goals and E-goals, which was expressed in general enlargement of these goals, in growth in the complexity of their mutual relationships and in arisal of "substitute" goals. Hierarchical relationships between C-goals and D-goals changed as well.

One fact that is significant from our point of view is that by capitalizing on the psychological factors of interaction between man and computer, revealed in our study, we can arrive at an effect much more simply than by the ways traditionally employed by the developers of modern automated systems. In their approach, a computer can be made a human partner only by raising its "intelligence." We believe that to have controlling influences on motivations similar to those influences that are specific to interaction between people, we do not necessarily have to make "computer intelligence" similar to human intelligence.

Our experimental data show in particular that by capitalizing on the psychological elements of computer-mediated communication between people as well as on the tendency to "personify the computer" (observed even among professional computer users), we can create conditions promoting arisal of the "motive to compete with the computer" in the individual, despite the fact that the possibilities for formalizing the real activity that was simulated in the experimental situation are highly limited today.

The obtained experimental data confirmed the hypothesis that autonomic parameters objectively recorded from an individual interacting with the computer in "dialogue" mode could be utilized. Inasmuch as the main difficulty of making practical use of this information lies in the polyfunctional nature of these parameters, confirmation of the possibility for using concrete motivation mechanisms to separate significant autonomic shifts from insignificant ones is a significant result of the research.

Under the influence of the competition motive, a certain redistribution occurred in the structure of emotional evaluations, which became more pronounced, and which therefore became easier to distinguish and which began to coincide more frequently with the objectively significant factors of the experimental situation. This permitted us to use them as a means for optimizing the "dialogue" mode itself: to create consistency between computer evaluations and concrete subjective evaluations of the products of activity in regard to the "originality" parameter, or to simulate such consistency.

In a number of cases autonomic parameters are indicators of certain changes in motivational factors; they may also reveal attempts by subjects to demonstrate false goals and false verbal evaluations of the products of their activity.

Using our data, we developed a number of premises which might be found useful to "dialogue" system planners.

1. When a computer is to be used to control creative processes, it would be suitable to develop modes of working with the computer which would possess specific degrees of freedom. This would allow the subject to independently regulate the conditions of his activity during his interaction with the computer; in particular, it would allow him to be more active in his search for an optimum combination of his own possibilities and the possibilities of the computer depending on the concrete features of his needs and motivations. We have also provided certain recommendations on the possibilities for capitalizing on the communication rhythm and on the "computer personification" phenomenon to raise the effectiveness of "dialogue" interaction.

2. Our method may be used to create practical methods for computer control of "idea generation."

3. Purposeful formation of a competition motive may be a means of active control of productive processes occurring in a computer "dialogue." The possibilities a computer has for moderating communication between people may be utilized to achieve

more-flexible, individualized selection of a "rival," which in turn would allow the subject to remain for a longer period of time in a zone best favoring development of his activity.

4. Objective autonomic parameters may be used to optimize computer control of productive processes, by the following means for example: a) by broadening the computer's evaluation functions in regard to not only verbal but also nonverbal data; b) by coordinating computer responses with concrete functional states of the individual at given moments of "dialogue" interaction; c) by permitting more-flexible change of modes and forms of interaction between man and computer.

THE TURING CRITERION, THINKING AND COMMUNICATION

A. Ye. Voyskunskiy

Attempts at comparing man with machine, at explaining his "structure" and behavior on analogy with the operating principles of technical systems and mechanisms have a distant history. It would be sufficient to recall that this idea very much aroused the interest of prominent intellectuals such as Leibniz, La Mettrie and Descartes. There has also been discussion of the theoretical possibility of creating artificial devices indistinguishable from man (this topic is even represented in urban folklore, for example in the legends of Frankenstein and Golem). Philosophers shared the opinion that simulating bodily functions would not be enough for this--no, such a device would necessarily have to be able to perform intellectual actions. Like it or not, such thoughts remained abstract, since none of the existing machines were at all promising as "candidates" for the role of intellectual creations. Whenever such were found, invariably they turned out to be hoaxes (such as Kempelin's "automatic chess machine").

Such machines finally did appear in the mid-20th century. The heated debates on whether or not a machine could think, brought on by cybernetics, are memorable to all. The appearance of cybernetic systems did in fact mark a new stage in the evolution of machines. Being information machines, they are invading all of those areas which had traditionally been thought of as intellectual. At one time it seemed that we were on the brink of programming a machine that really thinks. But it became clear in the 1970's that the "cybernetics boom" had not and could not bring this about. However, it was still permissible to doubt this in 1950. This is precisely when an article written by the famous English mathematician A. Turing was published (95). This article was fated to achieve broad notoriety.

"My objective is to examine the question: 'Can machines think?'," wrote Turing. "But for this purpose we would first need to define the meaning of the terms 'machine' and 'think'" ((95), p 19). He was dissatisfied by the definitions available in the philosophical literature, since it was impossible to directly "fit" them to a computer. Almost 20 years later I. A. Poletayev, one of the first Soviet cyberneticists, recalled that "the debate about 'a machine that thinks' bogged down at about the level where the cyberneticists declared: 'Define what you mean by thinking, and we'll program it in before you know it!', to which the proponents of 'spirituality' replied: 'Thinking is the highest form of reflection of reality.' As far as we know, no one has been able to program this definition" ((69), pp 10-11).

Turing found the solution by devising an operational procedure making comparison of human and machine thinking possible. He applied the "black box" principle, which was especially fashionable at the dawn of cybernetics. Unable to learn what is "inside" man, scientists learned to deduce certain conclusions by comparing the inputs to the outputs. Such was, for example, Shannon's original guessing method, with which he was able to establish the statistical laws of written text. As with Shannon as well as many other pioneers of cybernetics, Turing sought a way to utilize man's knowledge and ability to think without taking a single step toward understanding these processes.

For this purpose Turing developed the "imitation game." It is played by three persons--a man (A), a woman (B) and a person of either sex who asks the questions (C). The task of the latter is to enter into communication with A and B in order to determine which is the man and which is the woman. C cannot see his partners, and he communicates with them in writing, for example by telegraph. To A, the goal of the game is to cause C to come to the wrong conclusion, while to B it is to help C.

Having described the rules of the "imitation game," Turing continued: "Let us now ask: 'What would happen if a machine were to participate in the game instead of A?' Would the person asking the questions make mistakes as often as in a game in which only people participate? These questions will substitute for our initial question, 'Can machines think?'" ((95), p 20).

Such was the procedure Turing developed for determining the possibilities computers have for thinking. But he was not at all suggesting that it could be applied in the near future. The reason for this, we believe, is the inadequate development of the rules of the "imitation game" (this will be discussed below) and some random factors introduced to the procedure by Turing himself. Determining the sex of a correspondent on the basis of his written statement, for example, is not one of the stronger points of the "imitation game." It is difficult to look at this as anything more than arbitrary choice of a criterion. But at the same time the choice is a rather good one. In fact, after all, neither algorithms nor even any sort of unique methods of determining the sex of a partner on the basis of his written statements are likely to exist. In view of this, we might expect any unpredictable questions from player C, and the machine would have to be ready for this. Thus the "imitation game" completely ensures unpredictability of the situations in which the machine may find itself, and it demands a certain degree of universality from it.

Whatever the consequences, we will risk stating the conviction that the "imitation game" was perceived by most readers of Turing's articles free of random conditions arbitrarily introduced into the rules of the game. It appears to us that the essence of Turing's suggestion was interpreted as follows: If a person entering into communication fails to notice that his partner is a machine and not a man, then it can be said that this is a thinking machine. It seems to us that in addition to the "imitation game," this assertion, which transmits the essence of the procedure, may be assumed to be Turing's criterion (or test). This interpretation is confirmed by analysis of modern scientific publications.

This criterion was met with a certain amount of enthusiasm. There would be no purpose to dwelling on individual manifestations of this enthusiasm, but it would be worth recalling that Turing's criterion is still in scientific usage (only this, incidentally, can explain publication of this article). One qualification should be made here. Young researchers of "artificial intelligence" rarely ponder over machine thinking, Turing's criterion and other "philosophies" of this sort. However, for some specialists who are less pragmatically predisposed, Turing's criterion is a parcel of their theoretical baggage.

We will try to validate this with examples. "Turing invested a great deal of work into surmounting the deeply rooted prejudices suggesting that technical systems occupy an inferior position, and he categorized these prejudices. How much paper we could have saved today, had many distinguished authors writing on the topic 'Machines cannot think' attentively read Turing's work!" exclaims K. Shteynbukh ((108), p 438). Gelernter associated the prospects of meeting Turing's criterion with embodying the heuristic procedures discovered by (Poya) in a machine: "A machine which could operate on the basis of the complete set of principles indicated by Poya would be a superior device for solving mathematical problems, and it would mark a major step forward on the road to satisfying Turing's conditions for a machine which can deal successfully with the 'imitation game.' However, creation of such a machine is a matter of the indefinite future..." ((32), p 146).

Reytman describes Turing's procedure in detail. He discusses the possibility for meeting the criterion with a future system answering questions posed in natural language. A question-answer system proposed by B. Raphael, in Reytman's opinion, "clearly indicates the direction for development of new programs which would be capable of playing Turing's simple game, as described in his article, and winning((78), p 318). In contrast to him, Adler, the author of numerous books and director of the Chicago Institute of Philosophical Studies, does not share such a prediction. But this does not stop him from accepting Turing's point of view (114). Adler deduces from evolutionary and anthropological data that the most fundamental trait of intelligent man, characterizing him primarily and separating him from all other beings, is the capacity for articulate speech. It is in view of this that the "imitation game" impresses Adler so much: After all, it requires a mastery of language, and thus is directed at what is most important, it is "right on target" (132).

Such an attitude toward Turing's test is also typical of the present status of work on "artificial intelligence." Thus Aleksandrov not only cites Turing with the greatest sympathy but also concludes: "This statement of the 'imitation game' is unusually fruitful, and in view of its constructiveness it reduces the occasionally arising objections to naught" ((6), p 41). In relation to the heuristic approach to the "artificial intelligence" problem, Aleksandrov feels, Turing's criterion "is the methodological foundation."

Nor did Arbib ignore Turing's criterion: He believes that it is "much harder for a machine to pass Turing's 'test' than to behave in an intelligent manner" ((10), p 126). And therefore Arbib notes, "his (Turing's--*A.V.*) goal was not to find the necessary conditions of intelligence but to think up a test which, if passed by a computer, would persuade even the staunchest skeptics that intelligent machines do exist, and to reduce discussion of this test to discussion of the 'artificial intelligence' problem" ((10), p 127). A book written by the leading foreign critic of "artificial intelligence," Dreyfus, describes Turing's criterion in the greatest detail, after which it makes a cautious conclusion: "To a philosopher, simple similarity in behavior would probably be insufficient grounds for recognizing a machine to have intelligence, but nothing could beat Turing's test as the goal of the work of those who do in fact yearn to build a thinking machine, and as a criterion that could be used by critics evaluating the results of this work" (124).

Perhaps the following remarks, "scattered in passing" through the works of recent years, might be an even more persuasive proof of how contemporary Turing's criterion really is. Here are just a few examples: Nil'son, the author of one of the best contemporary books on "artificial intelligence," informs his reader: "Turing (1950) eliminated many of the standard arguments against thinking machines. To resolve the issue as to whether or not machines can think, he proposed a test which is now commonly called Turing's test" ((62), p 19). A cycle of works written under the guidance of a prominent specialist in human factors analysis, Chapanis, and devoted to comparative evaluation of different channels of communication between man and computer, points out that "idealized computer systems which will pass Turing's test" are being simulated in the laboratory (116). Mention should also be made of the words of one of the prominent modern ideologists of the "artificial intelligence" direction, Coles: "If we are nurturing hopes of solving important problems in 'artificial intelligence' such as the 'imitation game' proposed by Turing back in 1950 and known to this day as Turing's test," we would have to have mastery of natural language ((121), p 215).

References to the "imitation game" naturally do not imply complete agreement with Turing's idea. The procedure proposed by the latter may also be interpreted as a "convenient heuristic procedure," using Brudnyy's words (21). Brudnyy uses this "procedure" in a quite unique way: He builds an imaginary "dialogue" in which questions concerning the structure of the world, its objectivity and the nature of consciousness are asked. Quotations from works written by representatives of (L. Vitgenshteyn's) and (R. Karnap's) school of logical semantics are used as the responses. It is concluded as a result that the responses must have been generated by, of all things, a machine. And although this conclusion is not really correct, this should be the case from a theoretical standpoint. "In any case," notes Brudnyy in regard to the quotations used as responses, "the content of these impeccably formulated statements bears a certain 'nonhuman' imprint. In fact, Vitgenshteyn implied not man as such but a 'metaphysical subject,' an abstract bearer of the capacity for thinking, 'a thinking entity.' And were we to imagine a capacity for thinking that exists extrasocially and in total isolation from objective and practical reality, the manifestation of this capacity would be devoid of traits inherent to human thinking" ((21), p 173).

"Heuristic" use of Turing's procedure (in slightly modified form) led Brudnyy to this conclusion. Incidentally some authors are undertaking extremely active attempts to "revise" Turing's criterion. Abelson (113) has made the most progress. His effort will be discussed below. Amosov and his coauthor mention a "modification" of Turing's suggestion in passing: "We believe that an evaluation of the adequacy of plans, based on a comparison between psychological and computer experiments, may be interpreted as a modification of Turing's criterion for evaluating the 'intelligence' of the behavior of machines (models)." Later on the authors note: "In our experiment the behavior of the model was practically indistinguishable from that of the human subject ((8), pp 208-209).

Turing's criterion was useless as a means for testing a recently developed computer model of personal interaction (135). This interaction entailed generation of mutually associated personality parameters. Nevertheless the author was able to utilize

Turing's idea: Two real dialogues between people were encoded according to the same system at the basis of the computer model, and these record sheets were offered to a group of judges together with records of a "dialogue" with the computer. The judges were able to identify human interaction in only one case; they erred in the second. This, the author believes, to a certain extent confirms the "realism" of the model he created ((135), p 267).

Such "modifications" (which could hardly be treated as "heuristic" uses of Turing's procedure) are in company with reports of computer programs that have successfully passed Turing's test. It would be sufficient to mention a letter written by D. Bobrow (147), an American computer specialist. The fact that his listeners showed a preference for melodies composed by a computer (in accordance with a certain program) rather than by human composers meant that the program had passed Turing's test (97). The expression "inverse Turing criterion" has also slipped into the literature (106): The idea was that in some psychological experiments concerned with an operator's interaction with the computer, it is found to be advantageous to simulate the work of the computer in such a way that the subject believes the experimenter's responses to actually have been generated by the computer.

We believe that these examples are enough to confirm the fact that Turing's criterion is not at all of just historical interest alone. Of course, however, the fact that the "imitation game" is fully contemporary does not imply that the game has not encountered criticism. Highly significant remarks have been stated in opposition to Turing's proposal. Some of them rest on philosophical grounds (63,128,142) while others are grounded on mathematical logic. In order to refute the very possibility of machine thinking, some specialists brought up Godel's well known theorem on the incompleteness of formal theories. The limits of its application are not totally clear, however, as other authors hastened to recall (67).

We will not dwell on the criticism, valid in many ways, of Turing's test, since the progress that has been made in work on "artificial intelligence" permits us to carry its discussion to another plane, one which to our knowledge has not yet been subjected to criticism. Recognition of the theoretical significance of efforts at computer simulation of natural-language communication urges us to do so. We believe that the time to recognize this has come. Our discussion will center primarily on Weizenbaum's ELIZA program (27,150,155) (and its modifications) and Colby's program simulating paranoid verbal responses (117,118,119). We will first consider ELIZA, since it comes first chronologically and its principles are clearer.

The creators of ELIZA gave it only one objective--maintaining communication (in written form, by teletype) by natural language not limited in any way. This meant that ELIZA had to be ready to perceive any phrase whatsoever and generate an acceptable response. This task, which would appear to be beyond contemporary computer technology at first glance, was solved with surprising simplicity: ELIZA structures its response by modifying the inputted statement. As an example it may transform it into a question by changing pronouns and verbs from first to second person and adding a steriotypic introductory expression.

A specially compiled list of key words helps it identify the most significant part of the phrase. Other words and expressions situationally associated with the given element on the list are indicated as well. If the inputted phrase does not contain key words, ELIZA responds with one of several universal expressions foreseen for such a case and not disturbing the course of the discussion, or it may return to one of the previous phrases and build a response on its basis. Thus ELIZA is successful in maintaining a conversation entirely due to selection of a list of key words and expressions of universal applicability adequate to the given goals, and the clearness of the grammatical transformations built into it.

ELIZA allows change of "scenario"--the entire natural-language part of the program. Only the rules regulating interaction with an individual are rigidly programmed within it; the concrete linguistic expressions themselves may be easily substituted. This makes it possible to improve ELIZA as it acquires experience in communication. Moreover the program allows the scenario to be written in any language, and ELIZA instantly becomes capable of maintaining communication in the chosen language. Scenarios may be written by a person totally unfamiliar with programming. Such scenarios have already been written for several languages.

This basic information on the work of ELIZA is enough background for further discussion. We should now recall a very interesting experiment conducted with this program 10 years ago at the Massachusetts Institute of Technology as part of the well known MAC project (140). This project is concerned with using high-capacity computers on a time-sharing basis for operational interaction between man and computer. In the experiment, communication went on in real time; the authors note that the latent period between the moment the subject stopped typing a statement and the moment ELIZA began typing a response did not exceed 5 seconds.

The experiment was conducted in a psychological laboratory in which a terminal (a computer linking console) and a typewriter were installed. The terminal was linked to a high-capacity computer by a telephone cable. Twenty-four persons, including programmers, took part in the experiment. Each experimental session lasted exactly an hour. During this time individual subjects were able to feed 10 to 65 messages (an average of 22 messages) into the computer, and to receive as many responses. The subjects were informed that their partner was a computer; nevertheless, after finishing their session 15 persons (62 percent) felt that they had been communicating with a person, 5 (21 percent) were not sure and only 4 (17 percent) were convinced that the responses were from a computer. The researchers established that membership of a subject to any one of these groups correlated neither with the individual's competency in computer technology, nor with the intensity of interaction with the computer during the session, nor with the percentage of unsatisfactory ELIZA responses to messages fed in by these subjects.

This last finding is especially interesting and surprising. After the experiment, 19 percent of ELIZA's responses were recognized to be unsatisfactory--grammatically wrong or out of context. The bulk of such responses (85 percent) did not change the belief of the subjects that the "dialogue" was proceeding properly. Subjects made no association between an unsatisfactory response from the computer and their subsequent statement. They were prone to explain syntactic anomalies by interference in the communication channel, and in most cases they were able to interpret such sentences to their satisfaction. Subjects explained ELIZA responses that were out of context by suggesting that some other meaning had been imparted by their partner to the particular phrase, or they found justification for such statements in unusual motives of their partner (for example a subject might conclude that the partner is joking). Thus even clear program failures (which occurred with almost one out of every five statements) did not shake the belief of most subjects that their interlocutor was a person. Nor were they concerned by the fact that fragments of their own statements were repeated in each of the partner's responses.

Turing wrote in 1950: "I am certain that 50 years from now it will become possible to program the work of computers with a capacity of 10^9 bits in such a way that they could play the imitation game so well that the chance an average person would be able to establish the presence of machines within 5 minutes of the moment he begins asking questions would not exceed 70 percent" ((95), p 32). But as we can see, just a decade and a half was enough to drop the chances of an average person to firmly establish presence of machines after a 16-minute "dialogue" to 17 percent. Thus the ELIZA program was apparently the first to satisfy Turing's criterion, in its simple interpretation described above. This happened not only in special experimental conditions but also "impromptu" (147).

The first thing we should note is that ELIZA simulates not a single mental function and not a single aspect of thinking. Even the concept of understanding, without which it would seem that no question-answer system could do without, is reduced in this program to searching for key words. Thus this program, which has met Turing's criterion, can in no way be called a thinking program. But if the overwhelming majority of subjects maintained a conversation with it for an entire hour with obvious pleasure, does it not satisfy some sort of human need? The answer would have to be positive. In fact, communication with ELIZA very much recalls phatic communication. The sole meaningful purpose of such communication is to bring a group of interlocutors together. But this requires some explanation.

Malinowski, a well known English ethnographer, was the first to discuss phatic communication (134). His field work was concerned with the life of indigenous tribes whose representatives did not tend to distinguish speech from other forms of human behavior. When resting after work or performing uncomplicated work, these people exchanged words almost constantly. Malinowski discovered, however, that these words often had no relationship to the situation. "A simple expression of respect," he wrote, "one which is no less in the vogue among wild tribes than in European parlors, performs a function having almost nothing in common with the meaning of its words. When we inquire as to a person's health, remark about the weather or make assertions concerning a state of affairs that is obvious to the utmost as it is, we do so not to inform and not (in this case) to establish communication between acting people, and naturally not to express some particular thought" ((134), p 313). The sole purpose of exchanging such questions, remarks and assertions is to establish social interaction, and it is precisely such use of language which Malinowski called phatic communication. Any function of speech which establishes and maintains social contact is also naturally referred to as phatic.

Malinowski's observations and hypotheses quickly achieved the recognition of specialists. And in fact, all of the facts upon which he relied were indisputable and obvious. As Malinowski himself noted, "despite the fact that the examples were taken from the life of aborigines, we could find, in our society, the most exact parallel of each type of the uses of language examined to date" ((134), p 315). In this he is absolutely correct, and it would seem that any examples would be superfluous.

What is most interesting is that phatic communication belongs in the class of social phenomena. It is meaningless from the standpoint of intellectual interaction: The speaker does not transmit any idea, and he does not encourage the listener to perceive it. Thus in phatic communication there is no information transmitted, which provides the grounds for believing it to be a meaningless pastime. But goals need not exist on just the intellectual level alone; the social meaning of phatic communication is deep and indisputable. Of course the expressions which people actually exchange in phatic communication do not have great significance. They may even be totally out of context: What is important, after all, is only that they be uttered at the usual tempo and with ordinary intonation. As an example Laver (133) describes a little experiment performed by the English writer Dorothy Parker during a boring evening party. Whenever any of the casual acquaintenances turned to her with meaningless remarks the writer replied: "I just axe-murdered my husband and everything's fine." She said this in a sweet conversive tone, such that none of the guests paid any attention to the monstrous meaning behind the words spoken to them.

Let us return to the ELIZA program. It appears now that we can make this conclusion: It is intended for phatic communication. After all, the only goal posed to ELIZA is to maintain a conversation at any cost, without having it die out. This goal is achieved by maintaining contact--the main prerequisite of phatic communication. It is not even disturbed by statements that are out of context. But as had been discussed above, such statements are encountered in abundance in the experimental "dialogues" carried on by subjects with ELIZA. Thus phatic communication was found to be the easiest to model.

But this conclusion casts a troubling shadow over the validity of Turing's test. After all, it was passed by a program which simulates the social rather than the intellectual function of language. Thus it would seem that Turing's criterion does not test the capabilities for thinking, and that it has no bearing on intelligence. It may be hypothesized that only the capabilities for communication need be present to meet Turing's criterion. This does not mean that Turing was wrong when he suggested that "the question-and-answer method can be applied to any realm of human activity that we might wish to scrutinize" ((95), p 21). Dialogue can in fact be applied to the most diverse spheres of activity, and were we to expect ELIZA to come up with profound, intelligent responses to problems formulated for it, its anti-intellectual nature would manifest itself very quickly.

It is no accident that Weizenbaum asserts that ELIZA achieves the best results when it is taken to be a psychotherapist. Moreover, in his words, ELIZA parodies Rogers' system of psychotherapy, in which the patient's words are repeated and reworded (155). However, if Turing's test is to passed successfully (in the way Turing himself defined the problem), intelligent conversation on a narrowly specialized topic would not at all be required, and in our opinion attainment of the goal proposed by Turing--identifying the sex of the partner--does not differ very dramatically from a discussion with a psychiatrist: In both situations the simulating program must be prepared to answer all of the partner's questions.

Our ideas are based not on what Brudnyy (21) refers to as a "heuristic" interpretation of Turing's test, which does not of course raise any objections, but rather on the interpretation given by Turing himself. We already mentioned some attempts at making

Turing's criterion more complex. We will show below that at least some of these attempts have not altered the basic essence of Turing's proposal. This effort would be justified by the fact that attempts of this sort are still being made. Academician V. M. Glushkov essentially suggests developing Turing's test (some aspects of his statements have elicited criticism ((55), p 94): "Turing's criterion...remains unchallenged, and it implies that serious people will seriously converse with a machine, for a month or for a year and on any topic" (57). Dragging the "imitation game" out for a year is definitely not something Turing would have intended. Moreover, we could hardly expect such basically quantitative expansion of the test to occur without serious qualitative changes.

It should be noted that researchers have not concerned themselves with whether the results satisfy Turing's criterion or not (140). On the contrary it has been noted: "It is obvious that not a single discussion of a subject with a computer would have passed Turing's test, and it is just as obvious that most of the subjects drawn into conversation with the computer maintained it in the same way as they would a conversation with people" ((137), p 231). It would be difficult to agree with the first part of this conclusion. It would more likely be one reached by a casual observer evaluating the dialogue, and not at all by a participant of the dialogue, which is the only person with whom Turing is concerned. Thus the authors obviously have the intention of making Turing's criterion more complex in one way or another. This is surprising, since their experiments demonstrated the total hopelessness of attempts to determine, on the basis of the subject's behavior, who his interlocutor is, computer or a person. "...if our results receive confirmation," they write, "then in research on the use of computers for communication in natural language, it makes no difference what sort of instructions are given to the subjects, since they would always react in the same manner as if they were speaking with people" ((137), p 235). These words have the ring of condemnation of not only Turing's test but also the idea itself behind it, no matter how saddening this may be to his supporters.

And so, Turing's criterion tests for the presence of the capacity for communication. We feel that the experiment was purposefully designed in such a way that the computer's responses would be typed out at "human" speed, and that mistakes would sometimes "accidentally" slip into them (for example spaces between words may be left out (138,140)). To explain ELIZA's success we would need to analyze the mutual relationships between the partners of communication: We would need to determine those aspects of communicative technique which must be present for a partner to deem the conversation satisfactory, and those aspects which are less mandatory. But unfortunately not a single science studying human communication is presently able to provide a conclusive answer to this question.

Only some approaches to solving this problem can be noted. They are associated with an interest displayed by researchers in the pragmatic side of communication. For example some authors have analyzed cases of abnormal communication to arrive at those conditions which, if absent, would make communication meaningless (77). The authors of this work proposed a number of postulates of normal communication. Failure to satisfy any one of these postulates in an act of communication would make such communication abnormal. We analyzed this work and offered some suggestions in ((105), Chapter 5). Suggestion of communicative postulates was also attempted in a direction of linguistics that has come to be called "generative semantics" (126). The recent tendency among linguists to study real human communication must be recognized as fruitful. Linguists today are exhibiting a sustained interest in pragmatics (for example in sociolinguistics) and in research bordering between linguistics and logic (the teaching on presuppositions). In our opinion promising methods for analyzing the conditions of normal communication, ones capable of suggesting answers to some questions posed in the present article, may appear at the juncture of these directions.

It is interesting that the researchers who had conducted the ELIZA experiment compared speech interaction with a game and attempted to explain the success of their experiment from the standpoint of the rules of a game. They validly note that besides traditionally recognized phonological, syntactic and semantic rules, there are other rules of communication which govern interaction between partners in a communicative act. As an example the roles of speaker and listener are switched in accordance with certain rules. Communication is assessed to be satisfactory or unsatisfactory in accordance with other rules. Of course, the authors of (136,138, 139) did not make it their objective to arrive at a complete summary of the rules governing human communication. Such an objective would be unrealistic at the present time. Nevertheless these researchers were obviously right when they said that these rules exist and, moreover, that relatively speaking they are pretty much the same for all normal users of each natural language. This assumption permits the following hypothesis (137,138): If the initial stage of an act of communication satisfies rules of interaction implicitly known to the individual, the latter becomes certain that his partner also recognizes this system of rules in its entirety, and obeys it. But if the partner's messages subsequently become hard to interpret, this does not usually cause the individual to suppose that his partner was obeying different rules of oral communication. An experiment showed that other explanations of deviant oral behavior are usually sought (140).

The entire historical record suggests that only a human being is capable of using natural language: It is beyond the means of all animals and all artificial devices. Thus it is no surprise that subjects perceived ELIZA's responses as coming from a person. And if it is a person that is answering, he must adhere to the system of rules of communication common to all representatives of genus *Homo*. The attitude displayed by subjects toward a program responding in English may be compared with the echoes of the mythological relationship to the world so common to our ancestors. Here is what V. V. Ivanov wrote: "Many characteristics of human behavior become understandable if we accept the hypothesis that man processes every sequence of signals received by his senses as if it were an intelligent message (that is, man's starting point is that a message must be intelligent; this set would be typical of cryptologist). This class of phenomena includes not only ordinary linguistic communication (in which even knowingly unintelligent messages are perceived to be intelligent), but also attempts at interpreting natural phenomena as signs, which was especially typical of the earlier periods of human history" ((45), p 82). Considering this, it would now be proper to suggest, as an explanation for ELIZA's success, the hypothesis that all people are inherently predisposed to treat both nonlinguistic and (all the more so!) linguistic messages as intelligent. Throughout the centuries, this assumption has been unconditionally valid, but in the future it may lose its status if programs such as ELIZA enjoy greater application.

Starkweather (89) suggested the opinion that programs may be found to be useful to teach medical students how to talk with patients (89). The advantages would include the constant availability of the computer and the possibility for exercising communicative functions several times in succession; morecver, time-sharing makes it possible for dozens of students to undergo such training simultaneously. We believe, however, that for instructional purposes, specialized programs would be more suitable. For example, the responses of Colby's program to questions from a psychiatrist could not be distinguished by experts from the responses of a schizophrenic (118-120). ELIZA, meanwhile, is a general-purpose program to which some shortcomings are inherent. All human experience--among which the habits of communication are not an exception--is limited, such that the author of a scenario would unwittingly anticipate that communicative behavior with which he is familiar. This anticipated behavior is precisely what becomes the norm for the computer. But if a person with somewhat different habits of communication enters into communication with such a program, very probably the dialogue would fail. A similar opinion has been stated in the literature (140). Thus we cannot entrust teaching the art of talking with a patient completely to a computer, since such learning would be one-sided.

We can mention here as an analogy Greenblatt's reluctance to allow the chess program he created, MAKKhAK [not further identified], to participate in computer competitions. MAKKhAK is in all probability the most powerful chess program presently in existence: It has already been playing with people in official correspondence competitions for more than a year. According to some sources it is holding up against players with ratings* of 1,500 or even higher. Of course, this is far from the grand master's class (a rating of not less than 2,500); however, many amateur chess players never even reach this level, and thus MAKKhAK's strength is greater than theirs. We should note that recently former world champion R. Fisher, who challenged this program, won all three games played.

Greenblatt explains his refusal to pit MAKKhAK against other programs by the following: "Were my program to participate in a computer championship (right now it is just playing with people), I would wish it success. I would hope that its success would produce an advantage out of all the features characterizing a game between opponents. But in the final analysis this would lead to development of the program in a direction which is irrelevant to my end goal--successful play with people" ((153), p 26). Greenblatt validly suggests that every chess program embodies only the limited experience of its developers, and therefore neither a single program nor all of them put together can play the role of a teacher. We do not see any reason why this conclusion could not be carried over to question-answer communicative systems.

Our assertion that Turing's criterion tests communicative and not intellectual capacities requires additional discussion. First of all we need to answer the question as to whether or not it is valid to divorce intelligence from speech. There is no need to cite the numerous statements by philosophers and psychologists concerning the profound relationship existing between thinking and speech. Thus psycholinguistics faces one of the most difficult tasks of science: studying the limits, the

*An index officially adopted by the World Chess Federation (FIDE). It reflects the results achieved by chess players in competitive events. It is calculated by a special formula and it is used, as an example, to set the norms which must be met before a player's competitive rank could be raised.

movable boundaries of the mutual influence between thinking and speech. This problem is presented in the most logical form in a number of works by Zhinkin having to do with theoretical analysis of, experimentation on, and observation of speech pathology (39-42). We will take the liberty of dwelling briefly on these works.

"...no one has yet managed to come up with the facts demonstrating that thinking can proceed only through the resources of natural language," Zhinkin validly notes. "This has been an assertion only, but experience tells us something else" ((41), p 37). Distinguishing two blocks--intelligence and language, Zhinkin divides the former into three "subunits": the system of concepts on reality; the influence of emotions and motives; intellectual operations. In the language block he distinguishes "subunits" such as memory, intonation and linguistic operations (42). But what is most interesting is that Zhinkin is able to reveal the mechanism of joint coordinated work of both blocks during communication. Interaction of the two blocks is supported by an intermediate structure which lies between them and ties them together--semantics. "We would have to presume," Zhinkin wrote cautiously, "the existence of a special zone tying in the intelligence and language blocks. This zone is semantics" ((40), p 14). In that same year there appeared another work by the same author, in which the cited assumption was substantially confirmed (41). Clinical observation of a woman patient suffering semantic aphasia permitted him to refer more boldly to a "semantic filter" at the boundary between language and intelligence. This filter's job is to protect the intelligence block from meaningless messages (40).

It is not within our objective to examine the structure of the semantic zone. It would be sufficient to state that it evolves as the individual learns to correctly use language to express mental constructs. Zhinkin traces the entire path of communicative interaction--from the birth of a plan or a spoken idea to formation of the meaning of the stated words in the recipient's (the addressee's) head (42). But we are not interested in this at the moment. We wish to extract from this brief summary the conclusion that psychological theory, in its present state of development, fully allows us to refer separately to language and to intelligence, though of course not forgetting for a single minute that these entities are mutually associated. Thus theoretical psychology validates the conclusion that Turing's criterion may be concerned with speech and not with intellectual capacities.

It was already mentioned above that the imperfections of Turing's proposal were obvious to a large number of specialists from the very beginning. This encouraged some of them to improve the procedure of the "imitation game." Let us dwell on the attempt by Abelson (113), who went the farthest. Abelson turned his attention to the fact that Turing had said nothing about the degree to which player C was informed: Was he made aware of the possibility that a computer program might be participating in the experiment? In the case of a positive answer to this question, as Abelson validly notes, the subject (playing the role of player C or a judge) would change the strategy of his actions--that is, he would try to determine which room the computer is located in, rather than clarifying which of the players is a man and which is a woman. In an attempt to avoid this, while preserving Turing's basic idea Abelson developed stricter rules of the game. According to them, the game lasts for several sessions. The judge is told only that property which, depending on its presence or absence, would identify his two addressees (they could be distinguished not only by sex and age but also by intelligence). The percentage of correct responses by the judge--the base percentage--is determined from a series of sessions. At certain moments a computer enters the game as a substitute for one of the addressees, but the judge is not aware of this, such that from his point of view nothing has changed. In these sessions the percentage of correct responses by the judge is calculated separately (the computer program in a sense "inherits" all of the properties of the player it replaces). Thus the test percentage is determined.

If introduction of the computer into the game did not influence the judge's successfulness, this means that the computer program has successfully substituted for the subject. This may be stated more precisely: Imitation is successful if both the base and test percentages exceed 50 percent, with the test percentage not differing significantly (in the statistical sense) from the base percentage. If the computer successfully passes such an "expanded Turing test" in relation to a large number of contrasting differences (including intellectual differences), this would mean that it is hard to distinguish from a person.

However, even the expanded Turing test (as modified by Abelson) has already been passed. This was done with Colby's program simulating paranoia (117-120). Precisely this psychological disease was selected, Colby notes, because specialists are relatively agreed on what paranoia is. As far as other diseases are concerned, psychiatrists are less certain to reach a common opinion. The experiment with Colby's program was performed as follows. Eight psychotherapists interviewed three paranoic patients by teletype. From time to time a computer was substituted for the patients. The physicians were not aware that such a substitution was possible. They each conducted two interviews lasting 30-40 minutes, after which they were informed that they might have been conversing with a computer program. Each psychiatrist was asked to determine which of four situations was true in his case: both interviews were conducted with people; both were conducted with a computer; first with the computer and then with a person; first with a person and then with a computer. The fact that only two out of eight specialists answered correctly would have to be recognized as a product of random guessing.

This experimental design recalls Turing's proposal. The test was expanded after the first phase of the experiment: Records of interviews conducted with both the computer and a patient were sent to 105 randomly selected psychiatrists with the request to send back their conclusions. They were not told of the computer's participation. In 43 percent of the cases the 33 specialists that did reply considered the computer to have a more-severe form of paranoia than the real patient. This figure is close enough to 50 percent to suggest that once again the psychiatrists were unable to distinguish a person from a computer program.

The experiment continued. Another hundred psychiatrists were chosen at random. Each was sent two transcripts of the interview with a request to determine which interview was conducted with a person and which was conducted with the computer. This time 41 specialists responded, and only 21 answered correctly (which is 51 percent). Once again the results did not exceed the level of random guessing.

Next the experimenters tested the hypothesis that persons well acquainted with the possibilities of computers would be able to recognize the computer responses. For this purpose transcripts of interactions with the computer and with a patient were sent to 100 randomly selected members of the Association for Computing Machinery (ACM).

Out of 67 replies, 32 (48 percent) were correct, which would have to be recognized as a random level of guessing. Thus specialists in computer technology were also unable to determine which transcripts belonged to interaction with a computer and which represented interaction with a real patient. This result agrees with data obtained in the study examined above (136-141); however, its credibility is greater because it is supported by a statistical analysis ((118), p 92). A similar conclusion may be made relative to computer responses that are out of context. After the tests described above were completed ("in the spirit of Turing," Colby notes), the program was deliberately "worsened"--modified in such a way that it would select a concrete response in random fashion from among responses it had generated previously--that is, independently of the question at hand. As in the previous study (136-141), statements out of context did not influence the evaluation given to interaction between the modified program and the psychiatrist: Out of 69 specialists (this many persons sent in replies, though transcripts were sent to 200 randomly selected members of the American Psychiatric Association), 35 were unable to distinguish an interview conducted with this program from an interview with a paranoiac.

We will not dwell on the results of a survey of specialists conducted by Colby in order to clarify the parameters in relation to which responses generated by the computer program agree or disagree with responses by real patients. Data such as these may be used to improve a concrete program, though this is not what we are interested in at the moment. We will simply note that among the most significant disagreements (with a significance level of 0.001), the author implicated a factor connected with the linguistic competency of the program, with its poorer understanding, in comparison with real patients, of statements in natural language. It is no accident that improving the linguistic aspect of the program is now the focal point of the efforts of Colby and his colleagues (145).

Thus the expanded Turing test was now also met. It would be worthwhile to take a peek at the program with which this was made possible. Colby's program is akin to Weizenbaum's program in that exceptional attention is devoted to the linguistic support to interaction. Although Colby attempts to simulate the personality of a paranoiac, his main attention is concentrated on building adequate responses to questions from a psychiatrist. It may be said that Colby's program simulates mainly the oral reactions of a paranoiac, though it is based on some theoretical model of paranoid processes. As Weizenbaum wrote about this program, "there are no grounds for thinking that it might tell us something about the paranoiac just because it in a certain sense reflects the behavior of a paranoiac. Although a simple typewriter in a certain sense reflects the behavior of a shy child (it can type a question which does not receive any sort of reply), this in no way helps us to understand the nature of shyness. The validity of the model must be verify on the basis of theory" ((26), p 52).

Hence the former conclusion begs itself: A program which had successfully passed the expanded Turing test has remained entirely within the mainstream of communicative processes, without concerning itself in any way with intelligence. In this way it does not differ fundamentally in any way from ELIZA, meaning that expansion of the "imitation game" has not changed the fundamental essence of the game. As was asserted above, Turing's criterion tests only communicative capacities, and it tells us nothing about the presence or absence of intelligence. We believe that all possible expansions of this criterion (were they to materialize) would not change its fundamental nature. Intellectual capacities would have to be tested in a different way, and Turing's idea would not be any help in this; thus it is about time to decisively reject the notion that the "imitation game" (in its various modifications) is a criterion of intellectual activity. As is implied in Tikhomirov's article (94), rejection of Turing's criterion must be the first step on the "path of using psychological knowledge to raise the effectiveness of efforts to automate mental labor." The time for taking this step became ripe long ago.

In conclusion we would like to state a few remarks concerning the influence of research on "artificial intelligence" upon the theory of communication. The fact itself that practical efforts in "artificial intelligence" have led to problems which are within the competency of communication specialists must be recognized as surprising. It is especially curious that these problems have turned out to be the least developed in the entire conglomerate of sciences involved with communication. After all, serious study of phatic communication has not even begun yet, and scientists have only started talking about linguistic (and, equally so, nonlinguistic) conventions or postulates to which all individuals entering into communication adhere without noticing it.

Without a doubt these problems have always seemed very abstract, far away from practical things. But now practice itself has in a sense illuminated them with a bright searchlight and brought them to light from the deep shadows, attracting the attention of specialists to them. It is in this that we believe efforts in "artificial intelligence" have certain theoretical significance.

The entire area of "artificial intelligence" is now living through a difficult stage. We often hear references to a crisis in research on "artificial intelligence." Discussing this issue is not within our objective. However, we believe it possible to note that this scientific direction has occupied a certain place in the research front, and it is rather effectively promoting the synthesis of different sciences. In addition to the commonly known synthesis of sciences in the bionic direction, we can also say that efforts in "artificial intelligence" are also having an influence on research on human communication, this effect expressing itself as creation of interest in scientific problems that had previously seemed far afield of any sort of practical applications. Thus there is some merit to research on "artificial intelligence": It is attracting the attention of specialists to problems which have been on the periphery of the interests of representatives in those sciences having communication between people as their subject .

'ARTIFICIAL INTELLIGENCE' AND THE PROBLEMS OF COMMUNICATION

A. Ye. Voyskunskiy

Communication with a computer in natural languages occupies one of the places of honor on the list of problems facing specialists in "artificial intelligence." All of the problems addressed by research in "artificial intelligence," it is often admitted, are related rather closely to psychological research. On the other hand problems concerning communication have not been as lucky--that their discussion might require the support of psychological data is almost never considered. As a consequence we encounter uncriticial repetition of fuzzy and excessively general expressions and wordings behind which we sometimes fail to find concrete content. And yet work on systems supporting man's communication with a computer in a language close to natural needs psychological facts and psychological research no less than do other directions traditional to "artificial intelligence."

We will try to demonstrate this with a particular example. Indications of the ambiguity of the words and expressions of natural language, encountered in some linguistic works, are often interpreted by specialists in "artificial intelligence" as specially selected examples intended to demonstrate the complexity of natural language. The opinion has often been stated that ambiguous words are not used in real discussions between specialists (and all the more so in communication with a computer), that such discussions do not entail the use of technical sublanguages. However, it has been noted that to a speaking individual, the words he utters are fully unambiguous (1i2). This can be explained by the fact that the context (which is obvious to the speaker) imparts just one meaning to a word, and the speaker is simply unconscious of any other possible meanings. Thus we would have to forego the hope that people communicating with a computer would avoid ambiguous expressions. There can be no doubt from a psychological standpoint that a person acting as a speaker is incapable of recognizing the possibility of multiple interpretation of his speech, both at the level of words and the level of sentences.

But on the other hand ambiguity (for example that associated with homonyms) seriously encumbers speech perception by the listener. Let us make the qualification that it may become obvious to the speaker as well--then he corrects himself, placing his idea into an unambiguous context. But for this purpose the speaker must perceive his idea from the listener's position during the speech act, separating the uttered text from the process of its generation. The successfulness of such speech analysis, coinciding in time with the process of speaking itself, depends on how well the speaker's habits of communication are developed and on his capacity for standing in both positions.

It is no accident that we have raised the question of differences in the positions of the speaker and the listener here. The fact is that their interests in communication are not entirely identical: The speaker is interested in the most economical means for generating texts while the listener finds only the result--that is, the text itself--important. Every natural language is adapted, apparently to an equal degree, for speaking and for listening; nevertheless we cannot rightfully isolate the communicative interests of the speaker from those of the listener. Every natural language is a historical form of "compromise" between these diametrically opposed interests. Of course, in a dialogue the positions of speaker and listener are not fixed--the participants of communicative acts assume these positions alternately. Although only the speaker is actively engaged in speech at any given moment, he may not be able to realize his communicative interests to their full extent, since the probability is great that his message would not be understood by the partner. Thus the listener regulates (by feedback) the degree of compromise existing between diametrically opposed communicative interests.

It is difficult to clarify the communicative interests of the speaker and the listener because these interests are an inseparable element of the language system. Attempts at doing so are being made only in the field of typology: A comparison of several natural languages may reveal some forms of compromise that are expressed to different degrees in different languages (98).

The most distinct manifestation of the listener's communicative interests may be discerned in the requirement of redundancy of certain features of a statement. These may be, as an example, grammatical or acoustico-articulational features--the "building blocks" of language, defined as a system of contrasting elements at different levels. In syntagmic development of a statement, repetition of a certain feature (for example a plurality indicator) creates a redundancy advantageous to the listener, one facilitating adequate understanding of the text in the presence of unavoidable interference. It is known from information theory that repeated transmission of a meaningful element through a communication channel is not at all the most economical means of ensuring error-free reception of a text at the other end of the channel. There are more-sophisticated ways for introducing redundancy into a code. Nevertheless in natural languages we regularly encounter mechanical doubling of elements--a "primitive" resource from the standpoint of message transmission theory, and this indicates that for the sake of the listener's interests, the speaker is prepared to make rather uneconomical "sacrifices."

But we hardly need dwell on the obvious: The communicative interests of the speaker and the listener may be isolated only by abstraction from the real bearers of language, in relation to whom these interests are, naturally, within the realm of the unconscious. However, in addition to many other factors these communicative interests do have an influence on the evolution of natural languages. But to bearers of language, language exists on a synchronous cross section, apart from the individual's development, and every person accepts the compromise, gelled within the language system, between opposite communicative interests. It is only in pathology that this compromise may be violated; and in fact, the interests of the listener are often totally disregarded in the speech of aphasics. Texts produced by aphasics are sometimes compared with "telegraphic style": As we know, textual redundancy is partially eliminated in telegrams, and of course, such economy is not in the interests of the addressee.

Very little is known today about precisely what the communicative interests of the speaker and the listener are. Nor have experimental studies been performed to clarify the extent to which the speaker accounts for the listener's interests as he produces speech. Thus works in the psychology of influence (21) do not go beyond simply mentioning the fascination phenomenon, and no mention is made of the experimental approaches to its analysis. Fascinative signals are ones which "tune" the listener to reception of the information accompanying them. Fascinative signals act upon filters possessed by the listener, ones discussed by N. Viner and through which the message transmitted by the speaker must pass. Only that part of a message which passes through these filters is perceived by the listener and is capable of eliciting the effect the speaker was working toward. Thus the speaker is compelled to include, in the text he generates, signals creating favorable conditions for the listener's perception of this text. Thus fascination is one of the key phenomena in the complex mutual relationships between speaker and listener; as we said, however, research on it is only beginning (22,54,76).

This compromise evolved in natural languages wholly on the basis that both positions--both that of the speaker and that of the listener--have always been occupied by people--that is, beings with a similar nervous system and similar psychologycal potentials and limitations (allowing, of course, for individual differences). Must we carry this compromise into the realm of communication between man and machine? That is the implication when we suggest "teaching" a computer to understand natural language. I do not feel that this is the best direction in which to seek means of communication with a computer that would be optimum in relation to man. After all, if a computer not possessing psychological features and limitations inherent to man (an example might be the limitations of man's working memory) were to play the role of partner in communication, the individual would be able to fully realize his interests--both as a speaker and as a listener. In our opinion this could lead to development of communication resources specially intended for an individual in the position of a speaker or in the position of a listener, and these resources may turn out to be different.

During dialogue with a computer, the individual acts as both speaker and listener. We should make the qualification that not only acoustic communication with the computer but also more-standard written communication is implied, and the terms "speaker" and "listener" are, in this case, generalized names for the positions of, correspondingly, the message transmitter and the message receiver. Thus these terms will subsequently be used out of the context of oral communication between people.

The real contribution psychologists could make in one specific area of "artificial intelligence"--developing systems for communicating with a computer in a language close to natural--would be to study those resources of communicating with the computer which would be natural to man (a speaker or a listener).

Were we to make it our objective to immediately determine how natural a particular language of communication with a computer is to man, we would find it difficult to interpret the results, since we would have to account for a very large number of parameters. Therefore it would be more convenient to begin the analysis with individual fragments of language (syntactic constructs for example), which could be brought together in the future into a single language of communication with the computer. How natural such fragments are to man must be determined both when the individual occupies the speaker's position and when he occupies the listener's position. The latter has not yet attracted the attention of specialists, for which reason we will limit our discussion to the former.

Much attention is devoted in mathematical linguistics to one of the mechanisms of natural languages--self-nesting of clauses. This mechanism entails splitting a certain clause into two parts and "enclosing" another clause between them. The resulting phrase may in turn be split apart, and a new clause may be inserted into it. From a grammatical standpoint the number of such self-nesting operations can be unlimited. In reality, however, there is a certain limit, as follows from the "depth" hypothesis suggested by the American mathematician (V. Ingve) (47).

Beginning a phrase in natural language, we must memorize certain grammatical information about it and utilize it to finish off this phrase. Otherwise the statement would end up grammatically incorrect. In Ingve's words, our memory stores the "responsibility" of finishing a started clause correctly. According to Ingve's hypothesis the number of such intermediate bits of information which the working memory can store during creation of a phrase cannot exceed 7±2. The quantity of such memorized units, each of which reflects a particular step in the phrase's development, was called the "depth" of the phrase.

Self-nesting is one of the obvious means for increasing the "depth" of a phrase. The limits of man's psychological possibilities must have their effect in all communication, including with the computer. The suggestion that nesting constructs would be complex and unnatural to an individual transmitting a message to a computer (that is, to an individual occupying the position of the speaker) was refuted by experimental testing. The test was performed with materials contained in two types of conditional expressions that have enjoyed widespread acceptance in a number of programming languages. Two microlanguages were developed: Language A contained the nesting construct "if...then...otherwise...," while language B contained a construct with a transition to a marker "if...transition...." The problems were selected in such a way that their solution would require successive inspection of a number of conditions. In this case the programs for solving problems written in microlanguage A had to contain nesting constructs while this was impossible for programs written in microlanguage B. The experiment is described in detail in the book "Artificial Intelligence and Psychology" (50).

The experiment showed that subjects preferred microlanguage B. In a similar experiment, however, the results were directly opposite (154): The self-nesting construct was deemed the easiest. One of the possible reasons for the discrepancy in the experimental results is a difference between the problems offered to the subjects.

It is still early to make any final conclusions. Nevertheless we cannot exclude the probability that the constructs of natural language are not the most convenient resource of communication with the computer to an individual acting in the position of the speaker. Confirmation of this assumption requires numerous and meticulous experimental studies to compare individual linguistic fragments. The methods of such research have been described in sufficient detail by Glushkov and Timofeyev (35).

Only after conducting such studies can we appraise the opinion we stated earlier (50) that similarity of the language of man-computer interaction to natural language does not mean that this language of interaction is natural to the user. However, it should be noted that a similar point of view is being suggested and validated with increasingly greater frequency in the scientific literature. Thus Smul'son (87) makes a distinction between the linguistic and psychological naturalness of the language of man-computer interaction. Moyne (143) also asserts that similarity of the latter to natural language does not at all mean that it would be easy for the user to learn or that it is natural to man (the exact opposite may even be true). Moyne used the term "simple natural language" to mean language that best suits the interests of the user (Halpern called this active language (129)). He sets such language off against two tendencies: development of "pseudonatural languages" and development of languages "of the natural type" (differing in the principles of organization of linguistic processors).

Thus our point of view is directly confirmed by these authors, which permits us to conclude that these problems are important and that they require extended study from the standpoint of experimental psychology.

However, we are still far from any sort of final conclusions also because finding resources of speech communication with a computer that are convenient to man as a speaker is only half of the battle. Research conducted on natural languages may also provide significant assistance to studying human communication; in particular it may shed light on the communicative interests of the speaker and the listener and on the nature of the compromise between them. Thus the circle of psychological research would in a sense be closed. Having been started with the purpose of introducing the "human factor" into communication between man and computer (the particular features of communication between people were accounted for in this case), it will return full cycle to problems having to do with human communication (data on man-computer communication in natural languages would be utilized in this case). Were we to actually implement such a research program, it would serve as a unique example of how research in "artificial intelligence" can promote solution of specifically psychological (or psycholinguistic) problems.

THE COMPUTER USER'S RESPONSIBILITY FOR THE RESULTS OF ACTIVITY

L. I. Notkin

The responsibility of a computer user for decisions is one of the least-studied problems. Materials published on this problem tend more to simply state it than to actually study it (115,123,131). Despite the fact that the psychological content of the concept "responsibility" is not revealed directly in these works, its usage permits the suggestion that responsibility is usually associated with a motive having a situational and a conscious nature. Presence of conscious motives permitting the individual to voluntarily rank his immediate drives secondary to certain goals and intentions is viewed in psychology as one of the principal indicators of the personality's maturity, manifesting itself as independence of the influence of the situation, as a transition to qualitatively new levels of self-organization and self-regulation, as change in the relationship between the importance of the individual's evaluation of himself and the importance of the evaluation given by other persons, and as development of the mechanisms of self-exactingness and self-control. An irresponsible, inadequate, ill-conceived attitude toward one's acts is, on the other hand, one indication of the personality's immaturity. Such behavior is often characterized in pathopsychology as an indifferent attitude toward one's mistakes, as the inability to successfully complete an assignment without external control (44).

The first series of our experiments was devoted to research on the relationship between external control and self-control as the most important manifestation of responsibility.* We used B. Burdon's correcting test (73) as the basis for this series. The one difference was that rather than processing traditional correction tables, the subject was asked to give teletype replies to symbols displayed by a computer according to the following rule: Type symbol *Y* when symbol *G* appears, symbol *J* when *T* appears, *U* when *M* appears, *X* when *S* appears and *L* when *W* appears. If any other symbol appeared, the subject had to type the asterisk symbol. A program of 400 symbols was written in two modifications for two series of experiments**: In one of them, when the subject typed a wrong answer, prior to printing out the next symbol the computer informed the subject of his mistake; the subject was not informed of his mistakes in the other program. Print-out of a mistake signal was interpreted as control of the subject.

*The experimental method was proposed by O. K. Tikhomirov.
**The programs were written by Yu. D. Babayeva.

A total of 14 persons participated in the experiments, 7 in each series. The subjects included secondary school students in their senior years and college students. Each subject took part in only one experiment.

The instructions offered to both groups contained the rules of using the teletype machine and the rules of responding to appearing symbols. No indications were given relative to the speed and accuracy of the work. No limitations were imposed on the number of times the subjects could reread the instructions.

Seven subjects worked with the computer with the program providing mistake signals for 6 hours 39 minutes 28 seconds. All subjects made a total of 37 mistakes in this series. There was nothing to indicate that the interval between mistakes increased after a mistake signal was displayed. Bunching of wrong answers was the more typical pattern for subjects in this series. Thus for example, subject M, who typed 13 wrong answers, made mistakes on the 4th, 13th, 15th, 23d, 26th, 185th, 191st, 205th, 207th, 213th and 216th symbols. Subject K made three mistakes with the 5th, 7th and 21st symbols. Subjects I and L, who made a total of two mistakes each, did so with the 13th and 16th and the 78th and 85th symbols respectively. About two-thirds of the wrong answers in this series were typed with an average interval of three symbols.

According to interviews conducted following the experiment three of the subjects in this series, who had made 13, 5 and 4 mistakes respectively, felt the work to be monotonous and uninteresting. Subject Kh., who made two mistakes in the first 100 symbols, felt the work to be monotonous only in the beginning. In their reports, the subjects were generally correct in estimating the number of mistakes they made. Subject B underestimated the number of mistakes he had made.

Seven subjects worked with the computer using the program not providing a mistake signal (2,800 symbols) for 4 hours 30 minutes 28 seconds. The subjects made 22 mistakes. Much greater scatter was typical of the mistakes in this series of experiments. All subjects felt their work to be interesting and not monotonous. As in the first series the reports by these subjects generally indicated the true number of mistakes they made. Subjects M and A reported more mistakes than they had actually made.

Subjects in both series noted that they felt a sense of competition with the computer during their work, expressed as a rule as the desire not to fall behind the computer's symbol typing rate.

One unique feature of these experiments, making them different from B. Burdon's correcting tests, is that they did not contain so-called omitted symbols. The subject had to respond to each appearing symbol by typing an appropriate response. This circumstance prevented us from using the formulas usually employed to quantitatively determine the accuracy and productivity indicators of the subject's work (73). Therefore, following Binet's practice (15), we will limit ourselves to simply indicating the number of mistakes made as well as the time the subject worked.

The results show that mistake signals do not raise the subject's productivity. Mistake signals are sooner an interference to the activity of the subjects. Absence of mistake signals--that is, monopolization of activity control by the subject himself, and in this sense an increase in the feeling of responsibility, significantly raised productivity and the quality of the work.

Thus the problem of achieving an optimum relationship between the user's self-control and external control, which arises in the planning and organization of man-machine interaction, cannot be resolved uniquely. Despite its external expediency and objectivity, an error message may be subjectively perceived by the user as a superfluous, annoying reminder or even as harrassment, and it may reduce the effectiveness of his activity. These results are a confirmation of the "meaning barrier" effect, in which the subject remains in a sense impermeable to controlling influences (20).

An analysis of these experiments, which were performed to study the relationship between external control and self-control as a manifestation of responsibility, reveals that an examination of the responsibility of a computer user for adopted decisions cannot be limited to an examination of just the functional aspect of this problem alone. Being a motive, responsibility is obviously associated primarily not with the procedural but with the personal components of activity, with its meaning and purpose. Therefore the next experimental series was conducted to study division of responsibility for joint problem solving between man and computer in situations posing different goals to the subject.

A certain modification of the task proposed by the Hungarian psychologist (L. Sekey) (83) was presented in experiments simulating operational "dialogue" with a computer. The subject had to balance a scale in such a way that this balance would be disturbed after a certain amount of time without any outside interference. A number of objects were offered with which to balance the scale, to include a box of matches and a candle. To solve the problem, the subject had to balance a lit candle which, gradually burning down, would disturb the balance of the scale. The difficulty of this solution lay in the fact that the subject had to isolate a latent property in the candle--the decrease in its weight as it burned down. "Dialogue" with the computer was similated by the experimenter, who typed out the following 17 questions, in strict sequence, on a display linked to the subject's display*:

1. Number of paper clips, matches?**

2. Weight of each paper clip, paper clip box, match, matchbox?

3. Weight of the pencil, candle, bolt, nail?

4. What is meant by the words "about a minute"?

5. What is meant by the words "with outside interference"?

6. What is meant by the words "balancing the scale"?

7. What manipulations are possible with the objects?

8. Name the properties of the pencil.

9. Name the material of the box.

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*The method of simulating operational "dialogue" with a computer using paired displays was developed by V. B. Ryabov.

**The number and weight of the objects were given at the time they were described in the problem conditions.

10. Name the properties of cardboard (paper, wood).*

11. Name the properties of matches.

12. Name the properties of candles.

13. Name the properties of objects that can be used to solve the problem.

14. Is the expression "balance the scale" equivalent to "place objects with identical total weight on the pans of the scale"?

15. Can the balance, once it is established, be disturbed without outside interference? If yes, name some of the causes.

16. Are you familiar with objects which change their weight in response to one cause or another? If yes, name some of them.

17. Name the properties of objects listed in the problem as exemplified here: Nail--1) metal, 2) changes weight in response to: change in magnetic field, oxidation.

Although this procedure was run manually, it was fully within the means of a computer program. Not one of the subjects doubted that he was interacting with the computer. This provides the grounds for suggesting that the results may be applied within the context of planning and organizing real interaction between man and computer.

We used descriptions of the problem solving process published by Antsyferova (9) to develop the method of the experiment. Questions asked of the subjects during simulated interaction with the computer were worded in such a way as to cause the problem solving process to proceed through the three stages distinguished by Antsyferova. The 4th, 5th, 6th and 7th questions correspond to analysis of the basic requirements of the problem--establishment of an accurate balance, disturbance of the balance and noninterference. This was the first stage. The 8th, 9th, 10th, 11th, 12th, and 13th questions correspond to the second stage of the problem solving process--determining and analyzing the more-complex cause-and-effect relationships that require consideration of different properties of the objects. The 14th, 15th, 16th, and 17th questions correspond to the third stage, in which, following productive rewording of the basic requirement of the problem "change the balance of the scale" to "change the weight of objects on the balance," the subject seeks the properties of objects that could cause change in their weight. The first three questions were asked mainly for training purposes.

Because "communication" with the computer could proceed in natural language, scientists, college students and secondary students in their senior years who had never had any experience with computers or who did not know much about the possibilities of modern computers were included among the subjects. A total of 26 subjects took part in the experiments. Thirteen participated in each series. Each subject took part in an experiment once.

*This was the only question depending for its wording on a previous response from the subject.

The instructions offered to the subjects included the text of the problem and the rules of using the display necessary for "communication" with the computer. The difference in the instructions given to the two groups of subjects was that in one case the subject was required to present the problem to the computer for solution and then to "simply assist" it by answering questions that it may ask in the course of solution, while in the other it was emphasized that the problem is enormously difficult for the computer and that it could not be solved without effective assistance from the subject. In neither case was the subject directly required to solve the problem himself. It was presumed in this case that the second variant of the instructions would raise the subject's responsibility for problem solution--that is, that it would impart different meaning to the subject's goal.

After they acquainted themselves with the instructions the subjects of both groups began typing the text of the problem on their display screen and feeding it into the computer. Three minutes after the text of the problem was fed into the computer, the subject was presented the first question at a rate of 10 symbols per second. An interval of 30 seconds was established between a subject's response and each new question. Interaction with the computer entailed the asking of questions by the computer and the typing of answers by the user. After the subject answered the 17th question he was told that the time limit for the computer experiment had expired. Following the experiment the subject was asked the following questions: 1. Did you know the answer to the problem before analyzing it? 2. Was it interesting to you? 3. Recall the text of the problem. 4. Did you feel a sense of competition with the computer during the experiment? 5. Do you feel that you had a part in the problem's solution? If yes, then what did your participation consist of? 6. Do you know what the solution to the problem is now? If yes, explain it. 7. When did you figure out the solution to the problem?

Spontaneous statements and the behavior of the subjects were recorded during the experiment.

On processing the experimental data we revealed significant differences in both the results and the nature of the activity of subjects in the first and second group. Four subjects found the correct solution to the problem in the first series of experiments. In the second series 10 subjects solved the problem. We learned from the interviews that five subjects were interested in the problem in the first group, and eight persons were interested in it in the second. A sense of competition with the computer was stated by three and seven subjects respectively.

We were also highly interested in how the subjects described their role in the problem's solution.* Four subjects in the first group described their participation as providing additional data; one of them (subject V) stated the clarification that he did not try to solve the problem. Two subjects felt that they did not participate in the problem's solution. Subject L viewed his participation as "responses to unclear questions." The last two subjects described their participation rather indistinctly--as a form of feasible assistance. In the second group, out of three subjects who did not solve the problem two described their participation as <u>participation</u> in a search for the solution, and one described it as assistance.

*The responses of only those subjects who were unable to solve the problem were analyzed and compared.

What the subjects in the two groups said in their interviews was confirmed directly by data acquired during interaction with the computer. A reluctance to deviate from the text of the instructions and from the role of a simple intermediary between the experimenter and the "computer" was typical of subjects in the first group. This was expressed as recurrent requests for advice from the experimenter and as attempts to find, in the text of the instructions, literal indications as to what the responses should be to the questions from the "computer." Receiving no assistance from the instructions or the experimenter, the subject often typed arbitrary, inadequate responses.

Thus, naming a property of paper, subject P typed: "Thin material for writing." Among properties of a pencil, subject Kh. named its graphite core. When asked to name a property of matches, subject A replied: "Wooden, with green tips." Subject B's answer to question 16 was "Objects that change their weight exist, but I don't know any examples," and so on. Owing to this the responses of the subjects were often irrelevant to each other.

Thus, responding to the questions about the properties of the objects, subjects V and Kh. at first consistently named only those which had to do with their use as weights, and they asserted in response to question 13 that they did not know any properties that would be useful in the solution. The role of casual observer was most typical of subjects in this group is also confirmed by the fact that following the experiments the subjects often displayed an interest not in the solution itself but rather in how a certain solution was arrived at by the computer. Two out of four subjects who solved the problem were not certain that they had solved it correctly. It is interesting that many of the subjects in this group named loss of weight when burning as one of the properties of a candle in their responses, but they did not use this property to solve the problem.

Independent thinking without referrals to the instructions or the experimenter was more typical of subjects in the second group. Typing their responses, the subjects tried to make their wordings precise and unambiguous. Thus, describing the manipulations with the objects possible, subject F replies: "Rearranging the indicated objects," and he adds regretfully: "That word's imprecise." He also feels his description of the pencil's length to be imprecise. Not knowing how to answer the question about the properties of paper, subject F replies: "I don't know any properties having a bearing on the problem at hand."

Two out of the three subjects who had solved the problem, even after being asked all of the 17 questions, failed to name the property of losing weight when burning. They stubbornly named moistening and drying out of hydroscopic objects as the only cause of possible changes in weight. Such nonacceptance of hints differs significantly, in our opinion, from the inability to use hints to solve the problem, noted among subjects in the first series. The difference here is that the subject does make active attempts to solve the problem, though of course he is unable to progress beyond certain stages of its solution.

An analysis of the transcripts of the "dialogue" with the "computer" for participants in the first and second series that had solved the problem permits the hypothesis that in most cases the final wording of the solution was arrived at long before the questions were asked. Three of the subjects in the second series solved the problem before starting their interaction with the "computer" while one did so after.

Thus the activity of subjects in the second group was associated to a much lower degree with the "computer's" questions.

What was most typical of participants in this series of experiments was interest in the solution itself and not in the way the computer arrived at it. After the experiment the subjects often asked the experimenter whether or not they had found the right solution or what the solution was.

Thus the analysis of the responses given in the interview following "dialogue" with the "computer," of the content of questions asked by the experimenter at the end of the experiment, of the spontaneous statements made by subjects during "dialogue," and primarily of the responses to the "computer's" questions, can reveal significant differences in the actions of subjects in the first and second groups. These differences, which stem from the different degrees of responsibility for problem solution imposed by the instructions, manifested themselves basically as presence or absence of the problem solving process.

Taking Antsyferova's lead, we may assert the fact that in the experimentally "provoked" absence of the problem solving process or its incompleteness, the subject's effort to isolate the needed property did not lead to the use of this property to solve the problem. However, we also based our analysis of the experimental data on Soviet psychology's premise that "every spoken statement is a documentation of the results of thinking, one which cannot but have an influence on further thinking" ((80), p 95). We assumed in this case that the verbal statements of our subjects--that is, their replies to the "computer's" questions, were in one case a reflection of the solution process and were aimed at the goal--solving the problem, while in the other they were simply responses linked together by a series of questions. Nevertheless in both cases the verbal statements were in fact an expression of the thinking process (the sort of process is unimportant in this case)--that is, of analysis and synthesis, of inclusion of objects in new relationships and discovery of new properties within them, as well as of detection of mutual dependencies and the mutual exchangeability of the two positions.

In both cases the thinking process produced the "logical-objective prerequisites" ((80), p 71) of subsequent problem solving. In one case, however, they were used by the subject himself to arrive at the solution, while in the other they were interpreted by the subject as prerequisites for someone else's solution, the computer's in this case. Thus the method of our experiments permits us to distinctly reveal a situation in which a series of stated premises containing within themselves the means for successive transition from one premise to the next cannot be brought together into a single problem solving process, a situation in which presence of the procedural components of thinking does not yet predetermine its content.

To resolve the problems arising within the context of the situation described above, we considered S. L. Rubinshteyn's statement that "the course itself of problem solving creates the internal conditions for further advancement of thought; in this case these conditions include not only the logical-objective prerequisites but also the motives of thinking, its 'drivers'" ((80), p 71). Rubinshteyn's thesis that thinking is "self-motivated" essentially shifts the accent in research on thinking from the procedural to the personal aspect. Rubinshteyn's works contain no indications as to the reason for arisal of new motives in thinking: As we know, he limited himself to the suggestion that studying the personal aspect of thinking should be the next task of research on thinking. Our experiments permit the hypothesis that generation of new motives during thinking is associated with goal formation.

The following conclusions may be suggested on the basis of our experimental and theoretical analysis of responsibility associated with operational interaction between man and computer. Responsibility for decisions is a real factor, one which significantly determines the effectiveness of this interaction. The most important manifestation of responsibility is the subject's self-control during activity. Introduction of computer control over the individual may reduce self-control and the activity's productivity.

If the responsibility for the results of joint problem solving is relieved, the user may become passive in his interaction with the computer. The external manifestations of activity, particularly the characteristics desribing the state of an individual working with a computer (103) or the pace of communication, are still insufficient as indicators of the individual's participation in problem solving. Activity at the level of goal formation is the most productive form of activity. Raising responsibility for decisions is one of the means for controlling activity which leads to more-productive interaction with a computer.

PART II
PSYCHOLOGICAL PROBLEMS OF AUTOMATED CONTROL SYSTEMS

EXPERIENCE IN APPLYING PSYCHOLOGICAL KNOWLEDGE TO AUTOMATED CONTROL SYSTEM DEVELOPMENT

L. M. Berger, B. K. Koshkin

The Ministry of Electrical Equipment Industry's "El'fa" Association, which is developing manufacturing and engineering plans for ASU's [automated control systems], is turning special attention to a number of social and psychological problems that arise with introduction of ASU's: arisal of the "psychological barrier," change in the nature and content of the work of management employees in the new conditions, some problems associated with ASU training for personnel and with selection, recertification and retraining of personnel, the need expressed by "users" for computer information and the possibilities of using it, and consideration of the "human factor" in planning.

Consideration of these problems was prompted, on one hand, by the awareness displayed by the management of the ASU service in the importance of ASU's from a purely practical point of view. On the other hand presence of the theoretical base developed by colleagues of the USSR Academy of Sciences Institute of Psychology's Laboratory of Automation of Mental Labor (23,87,104,105) played an enormous role.

It was determined in 1972 that the "problem of psychological study of 'man-computer' systems is not only interdisciplinary, but it also spreads into other fields of science. It may be hypothesized that development of this problem will lead to formation of a new field of psychological science, one developing in close interaction with general and social psychology, the psychology of labor and art, engineering and pedagogical psychology, the psychology of science and the science of management, and so on" ((104), p 19).

This premise was laid at the basis of the planning effort. An attempt was made to examine social and psychological problems integrally.

An important role in formation of the conception behind this effort was played by the idea that "the effectiveness with which an ASU functions as a 'man-machine system' depends not only on the parameters of the computer but also on how well the functions of man and computer are distributed and 'mated' and on how well interaction between them is organized.... These problems can be solved only on the basis of psychological analysis..." ((23), p 95). The ensuing conclusion led to inclusion of a group of psychologists among the ASU developers. The ASU division of "El'fa" now contains an ASU psychosocial support sector.

This sector is working in three basic directions: 1) participation in ASU planning, 2) development of recommendations on introducing the plan and 3) activities associated directly with ASU introduction. These directions are distinguished from one another not so much due to their content as for organizational reasons.

The psychological requirements associated with the plan are based on the following principles: a) satisfying the cognitive needs of users; b) raising the quality and speed of decisions adopted and implemented by the individual; c) increasing the creative content of labor; d) allowing for voluntary regulation of the information flow; e) accounting for the individual features of the users; f) ensuring their job satisfaction; g) ensuring unity in the principles of improving automated and unautomated control ((105), pp 45-56).

Development of these problems would have been impossible without a theoretical base. But such a base does exist. Thus our study of the cognitive needs of users was based on research that has revealed the structure of the thinking of an individual solving creative problems (92). We defined the user's managerial activity as fulfillment of a production plan, and the evolved situation serves as the conditions for this activity. Our analysis of the sort of intermediate goals a user poses is based on experimental research (75).

The psychosocial support sector devotes special attention to the operational planning subsystem, mainly because special research has been conducted in this area (23,104). The results of research on the psychological structure of planning activity have permitted us to optimize the movement of information flows, raise the quality and efficiency of information and account for factors that raise the creative content of the labor of users and their job satisfaction. The sector is working on a method by which to account for their individual features.

The research and planning activity of the ASU psychosocial support sector is proceeding under the immediate scientific and methodological supervision of the USSR Academy of Sciences Institute of Psychology's Laboratory of Automation of Mental Labor. This supervision has made it possible to significantly raise the quality of the work done. Moreover the laboratory's participation in the sector's projects is significantly facilitating introduction of the planned projects and promoting interaction between the sector and other subdivisions involved in ASU planning and introduction.

Recommendations on ASU introduction are being written basically according to the same principles. What is most important here is to achieve unity in the principles of improving automated and unautomated control. One of the associated problems is that of preparing the user for work in the new conditions. The theoretical grounds of this effort are provided in the book "Man and Computer" (104). The computer only creates a possibility for improving the structure of human activity. This possibility is realized when certain technical, psychological and social conditions are met.

The psychological conditions require that the individual be adapted "to the conditions of working with a computer" ((104), p 261). Therefore the main recommendation must be to ensure presence of the psychological conditions promoting improvement of activity. This goal is achieved by implementing a broad program of measures in all stages of the ASU's creation. This program embraces a large number of areas, to include improving the control system, preparing and training personnel, advertising and publicizing the ASU, and so on. The sector is working on standard recommendations to be introduced into enterprises of the Ministry of Electrical Equipment Industry.

The effectiveness of the individual measures is being verified through special research at the "El'fa" Association. The objects of this research include some features of the thinking activity of users, the "psychological barrier" to creation of the ASU and the structure of interpersonal relationships in the enterprise management.

The immediate purpose of the ASU introduction sector is to implement the plans and recommendations. The sector is encountering significant organizational difficulties in this effort: absence of a statute explaining the functions of the ASU psychosocial service, and of guidelines general to the sector; absence of state or sector directives stating the importance and necessity of psychosocial research; the unofficial nature of scientific supervision given to the sector's work.

Although interest in social and psychological problems is constantly growing, creation of the appropriate study groups at other enterprises is often hindered by the organizational difficulties listed above. We can sense an acute need for creating a single center to coordinate work on the psychosocial problems of ASU's, and for developing and publishing the appropriate guidelines.

Moreover the scientific research on these problems must be brought together under a single program. From our point of view such a program could be developed as part of the research effort on the "artificial intelligence" problem. It is only by combining the work of different scientific-theoretical and applied (planning) collectives within the framework of such a program of integrated study of these problems that we can ensure effective consideration of the psychosocial factors associated with ASU creation.

Let us now dwell on two special problems of accounting for these factors.

Goal Formation and Creation of Information* Needs

One of the most important problems of creating an automated enterprise control system (ASUP) is to determine the information needs of the employees. Two basic methods are used in practice--building an economic model of employee functions, and expert interview. What the developer gets in both cases is not data on the real need for information but a theoretical idea of this need. He must therefore reveal the real information needs by studying the activity of ASUP users directly.

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*The term "information" is used in this context in its traditional meaning, and not in a special one.

In this case the object of study would have to be goal formation in enterprise control activity, inasmuch as "the need for information depends on the content of the corresponding problems..." ((104), p 167). He would be required to establish the direct ties existing between the goal of an action and the information supporting attainment of this goal. No less significant is the "information--goal of action" relationship, since the process of goal formation regulates to a significant extent the kind of information that is obtained. "We must organize information processes in such a way that every employee and the collective as a whole would know not only what the task is and how it must be completed, but also why (that is, the significance of the collective's task to the enterprise and to society in general)" ((104), p 169).

The system of operational planning of the enterprise's work was chosen as the object of analysis. The end goal of this system's colleagues is to fulfill their plan. We know, however, that other secondary goals exist on par with this goal--establishing good mutual relationships with subordinates, earning the respect of a supervisor and so on. All of these goals are closely associated with the overall task, and therefore fulfillment of the plan also means attainment of other goals.

When we subdivide this plan into intermediate goals, we can distinguish a number of basic functions requiring information support: 1) acquainting the employee with the plan, 2) acquainting the employee with the real situation at the facility for which the plan is being created, 3) searching for the possibilities of supporting plan fulfillment, 4) monitoring its fulfillment. Each of these functions is in turn associated with formation of intermediate goals. Therefore it would seem best to examine these functions as independent stages. In this case we may ignore the fact that they may coincide or overlap in time.

1. As a person familiarizes himself with a plan, he becomes aware of the basic goals of the planner's activity, which in turn generates new needs for information. This process is regulated by the interests and predispositions of the planner. Thus for example, "an enterprise executive interested in product marketing problems...may demand, besides information necessary to the enterprise's management, detailed information on the possibilities of selling the enterprise's products" ((23), p 74). Our research revealed that some executives exhibited greater interest in the plans of subdivisions at a higher level (the global approach), in the procedures of the plan's creation (the genetic approach) or in the plans of similar enterprises (the comparative approach). The general line of the executive's goals changes in accordance with the approach he takes. An executive taking the global approach requires a clear understanding of the tasks facing the enterprise; he requires not only verbatim fulfillment of the plan, but also fulfillment of the demands it expresses between the lines. The procedural approach is in keeping with more-formal fulfillment of the plan, with an orientation toward "good" accountability at any cost--it is precisely in this case that we often encounter the tendency to make untrue, exaggerated reports, to raise certain indicators at the expense of others, with an eye on what subjective evaluation higher supervisors might give. The comparative approach is associated with competing tendencies, with an orientation toward performance "no worse than others'" in plan fulfillment.

Our research included experiments with imposed changes in the structure of information used in decision making. These experiments showed that the influence of information on goal formation is extremely limited in this stage. Information outside the limits of the user's needs is hardly perceived at all. Users believe such information to be superfluous: "Who needs this?", "I don't have time for all of this nonsense!", and so on. When the subject finds it impossible to avoid perceiving subjectively superfluous information, the result is contradictory: On one hand he develops a negative attitude toward the experiment, in general, losing all interest in the imposed information, and as a consequence the information is perceived but not assimilated; on the other hand his need for subjectively necessary information grows. This result permits the assertion that when a person familiarizes himself with a plan, goal formation dominates over formation of information needs, and it predetermines the composition of subjectively necessary information.

2. When acquainting himself with the real situation at the facility for which the plan is being drawn up, the planner uses both information directly acquired during planning and information accumulated in the past (the so-called "knowledge of the facility"). Therefore the information need varies significantly depending on the extent to which this person is informed about the facility, and it takes the form of the need to acquire information supplementary to that already available. Using the "supplementary" principle we can subdivide all information on the state of a facility into general and variable--that is, into information that compensates for an inadequate knowledge of the facility and information which supplements this knowledge with a knowledge of the immediate situation.

The need for general information is obviously determined uniquely by the accumulated knowledge. At the same time accumulated knowledge is to a significant extent unconscious knowledge, and it yields to analysis with great difficulty. This is why we concentrated our attention mainly on variable information.

One of the most interesting facts revealed in our analysis was the planners' gross exaggeration of their information needs. This tendency manifested itself especially clearly in interviews. At the shop chief level, for example, interviews revealed a daily need which significantly exceeded the amount of information actually received at the given moment; however, the shop chief spends up to 30 percent of his work day analyzing the received information (this includes time spent on its perception), and he is not in a position to devote more time of any significance to this activity. At the same time, production executives often demand that information about the status of the facility be transmitted to them as frequently as possible, more frequently than they are capable of using it in decision making. It has already been noted in the literature that "if management units receive information in time intervals that are so short that they cannot assimilate it well enough to make effective decisions, the only result is unjustified additional outlays of labor" ((104), p 44).

At the same time the interviews revealed extremely few complaints that the form in which information is presented is inconvenient, and particularly that its appearance in different documents makes it redundant, even though presence of such redundancy may have been demonstrated by research on document turnover conducted by the ASU planning division before starting work on the plan. There can only be one explanation for this phenomenon--goal displacement, displacement of the planner's end goal by one of the intermediate goals. Inasmuch as gaining an acquaintance with certain documents is an intermediate goal to clarifying the situation at a facility, the process itself of familiarization becomes a need. An indirect confirmation of this premise may be found in the unique jargon used by management personnel: Rather than "Set the assignment for the shop," they say "Include the shop in the plan";

rather than "Check up on plan fulfillment," they say "Review the daily report" and so on. Here, operations with the documents become the goal, and the real goal fades into the background. Hence also the format of the document is perceived as something absolute, determined forever and not subject to discussion.

Thus although the goal at hand predetermines the information need in this case, the goal itself forms (or, more accurately, undergoes transformation) under the influence of those forms in which this need is satisfied. Here, goal formation exists in a complex dialectical relationship with formation and satisfaction of an information need. It may consequently be hypothesized that when the composition of incoming information changes, the goal of the planner changes as well.

The analysis also revealed another case of goal displacement. The planner of an operating system tries to plan not so much the end goal itself as a smoothly running production operation--that is, absence of manpower and equipment idleness, timely delivery of raw materials, semifinished products and associated articles, fulfillment of labor discipline norms and so on. The information need changes correspondingly as well: The planner is interested mainly in information on production deviations, and he rejects information having to do with a normal course of production. But the real goal of a manager is not to correct disturbances in a normal production operation but to prevent such disturbances by prompt action. Therefore predictions of deviations, ones allowing the manager to foretell possible interruptions in production, are objectively necessary information.

N. N. Slyun'kov, director of the Minsk Tractor Plant, discerned this phenomenon with surprising accuracy: "The actual stoppage of a conveyer had always been the disaster signal, and it was at that time that emergency measures were implemented. And as long as the conveyer was still running, it was thought, there was no reason to raise a fuss. But an order making preventive maintenance mandatory imparted rhythmicity to the work of our conveyer, and on the other hand it changed the viewpoints of the people. It was some time before the laborers and specialists became accustomed to the simple idea that emergency measures should be implemented before the fact, and that our objective is not to get the conveyer running once again through heroic effort. It must never be allowed to stop--this simple idea came into acceptance with agonizing difficulty" (88).

In our experiment, predictions of possible failures did not produce a dramatic change in the structure of intermediate goals (a change from correction of failures to their prevention). It may be supposed, however, that the desired impact would be achieved after the practice of providing such information has existed for a longer period of time.

3. Finding the possibilities for changing the situation at the target facility with the purpose of supporting plan fulfillment is the most complex stage. What we are dealing with here is a function of operational planning that is the key to the entire planning system--formation of the plan of action to achieve the planned goal. This function may also be interpreted as the making of a planning decision, since the search for the means of making the decision is inseparable from the choice of the best decision. The information used in this case is distinguished by both great diversity and high uncertainty. Additional difficulties are associated with the fact that the bulk of the necessary information is selected and perceived by the

planner nondeliberately, randomly to a certain extent. Therefore neither the experiment nor the interviews produced reliable results, and so the analysis rested basically on observations of the activity.

The field of decision making resources is limited almost entirely to two forms of information: a) accumulated experience, b) the theoretical recommendations of colleagues (including subordinates, supervisors and even "plain old acquaintenances"). Theoretical recommendations have relatively little value to production managers due to their excessively general nature: "...they need concrete reference information which may be utilized right away. The information interests of these users are forced upon them by the circumstances" ((92), p 12). If we add to this that most managers received their special education a rather long time ago and that their knowledge is to a significant extent obsolete, it becomes clear that the theoretical knowledge possessed by production executives comes entirely from personal experience acquired in the given job or at the given enterprise.

Personal experience is transformed into a certain system of relationships between certain decisions and frequently encountered problems. The task of the planner boils down here to reducing the existing situation to a past situation (seeking a precedent). In this case, external advice changes almost nothing: The personal experience of the subject of planning is simply substituted by the personal experience of the "consultant." If a precedent is found, the decision is brought into concrete form on the basis of information describing specific aspects of the situation. At this moment the information need centers on specific aspects depending on the precedent chosen. For a certain while the precedent itself--the decision selected in the past--assumes the role of the goal.

The definition given to the end goal by the subject of planning plays a tremendous role. To many managers this goal is the desire to eliminate disturbances of the production cycle at all costs. In this case the information need is limited to the given disturbances--their depth, their duration, the external causes, the persons at fault (more accurately, the persons responsible) and their significance from the reporting standpoint. A decision eliminating the failure itself is adopted correspondingly. The range of action of a decision is limited to the current situation. The possibility that a given failure may recur is not accounted for to a sufficient degree, and in the best case, someone is made personally responsible for failures in an effort to prevent such failures in the future.

But the real goal of management, as it is defined by the most successful executives, is not to correct a disturbance but to eliminate its causes. In this case the decision must be deeper, more far-reaching, and predictive to some extent. Specifically speaking, only such a decision can be called a planning decision. When planning is performed in this way the information need rises significantly. The information must support analysis of the activity of the target of planning over a significant time interval, prediction of its activity in the future and determination of the possibility for maintaining a long-term influence upon the facility.

Thus, here as well we encounter change in information need under the influence of the way the end goal is defined. At the same time, formation of the intermediate goal depends on how well this need is satisfied. The way extended provision of this certain information in this stage influences the possibilities for change in the orientation of goals was not analyzed.

4. The fourth stage of operational planning--control over plan fulfillment--is closely associated with familiarization with the real situation. The fact is that plan fulfillment data for a current period simultaneously represent information necessary for future planning, assuming that these data are promptly received. The results of our analysis show that ignoring the specific needs for control information would not be detrimental to the overall picture.

Summarizing the results, we can make the following conclusion: The information needs of a manager in an operational planning system are formed under the influence of the main goal of action, as subjectively defined. Intermediate goals, on the other hand, are formed under the direct influence of the received information. Thus the relationship between the end goal and intermediate goals is found to be indirect, mediated by the information need and by its satisfaction. Provision of subjectively superfluous but objectively necessary information does not have a direct influence on the results of activity, but were such information to be provided over a long period of time, it could influence the definition of the end goal and, consequently, the information need. Formation of new information needs is the external manifestation of this influence.

Consequently we cannot base a definition of the structure and volume of output information in an ASUP on the existing information needs. Automation of control opens up new possibilities before users, ones which they cannot put into action without special training. Consequently we need to determine what data are objectively necessary, and then train the user to use them. In this case the way the information is presented is itself one of the factors to be considered in manager training.

Characteristics of Goal Formation in Managerial Activity

Operational planning is defined in the economic literature as a means for achieving a single goal--fulfillment of a production plan. "By promoting smooth and coordinated operation of all production units with the goal of achieving uniform fulfillment of the production plan in terms of specified volumes and assortment, operational planning thus promotes rhythmical work of the enterprise..." ((103), p 3). However, the goal of the whole system may not be consistent with the goals of individual workers--the executors in this system.

Internal shop planning performed by foremen (section chiefs) and senior foremen (shift chiefs) was adopted as the object of study. We used a method of active observation of the work of the foremen to reveal those factors which most actively influence goal formation.

The study was based on division of all forms of planning information into three categories: the target plan, the plan of action and the follow-up plan. The target plan was defined as the complex of indicators that had to be achieved as a result of the activity of the section (shift) workers, assuming that the means for achieving these indicators are not specified by plan. The plan of action is defined as the set of resources promoting attainment of the target plan; in other words it is a concrete guide for action. The follow-up plan was defined as a planning document not having mandatory force and used to monitor and record fulfillment of the target plan; an example of such a plan would be a section's monthly work plan, if deviations from this plan, occurring within the month (or a 10-day period), are said to be permissible.

The target plan and the follow-up plan are submitted to the foreman in ready form "from above"--from the plant's plan dispatch department (PDO) or the shop's plan dispatch bureau (PDB). The foreman creates (or should create) the plan of action independently or with the help of subordinates. An analysis of the plan of action would lead to a number of conclusions concerning the foreman's relationship to different components of the target plan and concerning presence of other goals posed by the foreman in the performance of his official responsibilities. Inasmuch as the plan of action is usually not documented, and sometimes not even verbalized, analysis of this plan was based on a study of the actions themselves. It was assumed in this case, with a certain amount of arbitrariness, that all actions of the foreman are aimed at fulfillment of a certain plan, conscious or unconscious.

The results of the analysis allow the assertion that fulfillment of the target plan is, to the foreman, only a means for achieving goals at a subjectively higher level. Such goals include positive evaluations of the foreman's activity by different evaluating groups. A foreman has three such groups: the shop management and, in part, the management of the entire plant, the shop administration collective, and the collective of workers directly subordinated to the master. Contradictions in the opinions and evaluations of different groups elicit corresponding contradictions in the goals of the foreman.

The management evaluates the foreman's activities on the basis of production indicators: fulfillment of the target plan, compliance with technical and procedural standards, maintenance of labor discipline at the required level, economization of materials and the wage fund, equipment maintenance, production rhythmicity and so on. In this case the manager is quite happy if the foreman is able to satisfy certain norms established by custom. Within the limits of these norms, the foreman's activity is usually not questioned, assuming that the manager does not receive additional "external" signals . Thus from the manager's standpoint the best foreman is one who is able to satisfy universally recognized norms of activity, one who keeps "everything in order," and whose actions never require the manager's interference. One other condition is included here rather often as well: The foreman should turn to the manager for help in solving complex problems as rarely as possible.

From the standpoint of his colleagues the foreman must: first, "not be better than everyone else," not be too far ahead of the other sections (shifts), and not force other foremen to change their work style and methods by personal example; second, he must fulfill his responsibilities as independently as possible, without running to his comrades for help and without distracting them from their own responsibilities; third, he must uniformly share general responsibilities with neighboring sections (shifts), he should not "profit at the expense of others." To satisfy these requirements, the foreman must often reduce his work effectiveness, fail some of his responsibilities, and work at the lower limit of managerial expertise when a possibility for working more effectively does exist.

The requirements imposed on the foreman by his workers may be divided into two groups. First of all there are those consistent with the management's requirements in relation to production indicators--the workers are basically interested in the section's (shift's) effective work, and as a minimum in a high evaluation of this effectiveness by the management. But the workers also have specific requirements toward their foreman associated with a narrow approach to the section's activity, with a tendency to solve their own problems at the expense of external resources. The foreman must defend their interests, in the opinion of most interviewed workers, namely "at the expense of others," no matter what the problem--expenditure of the wage fund, the quality of raw materials and semifinished products and their delivery schedule, or the use of repairmen. The interviews clearly revealed the need of the workers for a foreman able to have the needs of his section and of his workers satisfied first. This factor acquires special significance in regard to material stimulation, to include distribution of "profitable" and "unprofitable" jobs, determination of output norms, overtime pay and so on.

The contradictory nature of the interests of different groups making value judgments of the foreman is an inherent trait of the complex network of overlapping and conflicting interests in national economic planning. "...the probability is not excluded that the state plan's assignments, which reflect national needs and which are brought to the awareness of the production collective, may not be consistent with its interests; as an example the average profitability level or the product sales volume of the enterprise may be decreased" ((23), p 36). "The mutual relationships between the economic planning department (PEO) and the production dispatch department (PDO) make up one of the most confused and complex areas of management. Their operating mechanism is itself characterized by a certain inconsistency in individual parts of this mechanism.... Under these conditions the PDO's work...boils down to 'tailoring' the production plan to economic indicators calculated without regard to the actual status and temporal dynamics of production, and to controlling production on a real time scale, having to deal not with 'comparison' articles and not only norm-hours but also natural, 'physical' indicators ((104), p 544).

Returning to the activity of the foreman, we find that it is aimed at reaching contradictory, incompatible goals. We know "that in addition to an end goal, intermediate goals formed independently by the subject depending on the evolved conditions play a highly important role in the subject's activity" ((88), p 20). Formation of such intermediate goals, associated to one extent or another with the end goals, promote the latter's attainment, and in our opinion they represent the goal formation process in the foreman's activity and, by the way, in the activity of any manager.

Our research revealed a certain set of typical, most frequently proposed goals. An analysis of the causes and conditions of their formation would permit us to gain a better understanding of the foreman's activity and of the laws governing goal formation. One of the most complex functions of the foreman is to distribute shift assignments between workplaces containing identical or functionally similar equipment. (In this case we are dealing with various types of stamps.) Individual series of parts differ in volume--large series should be sent to the more-productive machine tools so as to reduce the number of times the tools must be readjusted (the number of times the stamps must be changed). Because some norms that do not account for the specific features of certain parts cannot be met, jobs may be more profitable or less profitable (norms may be more or less intensive), which makes it necessary to distribute the jobs uniformly in terms of the possible income. This uniformity is violated when the foreman tries to use profitable jobs as a means of material stimulation, and by the fact that the wage interests of different workers are not the same. Orders can also differ in terms of their completion deadline, and therefore the foreman must account for both the reliability of the equipment and the possibilities of the worker. The need for simultaneously accounting for all of these factors considerably raises the load on the mental capabilities of an individual faced by a rather large volume of jobs (when there are 50-100 persons in a section).

Judging from the observation results the foreman structures his chain of intermediate goals depending on the degree to which their attainment is controlled. Rush orders are given priority--they are assigned to the most reliable and experienced workers using the most reliable and productive machine tools. This pertains to orders fulfilled in response to dispatch warning signals (controlled by the plant PDO), to the personal directives of the shop chief (personal control) and to orders upon which satisfaction of monthly norms depends (controlled by bonuses).

When this goal is met, the foreman sets a second goal--satisfaction of the most serious wage complaints of the workers. Because frequent machine tool readjustments are not in the interests of the workers--per-worker output and wages decrease, distribution of jobs in relation to their profitability also partially solves the problem of loading the equipment in the most effective way. And it is only after this second goal is attained that a new goal of action rises to the surface--distribution of jobs with maximum economic impact, with maximum labor productivity.

This displacement of what would seem to be the main goal--raising labor productivity--to last place requires special explanation. First, this goal is partially reached when the other goals are met, inasmuch as the paths of their attainment coincide. Second, the workers themselves are interested in their own productivity even more than is the foreman (at least from the standpoint of material stimulation). Third, labor productivity as such is not controlled specially, the moral and material stimulation it receives is relatively weak, and not one of the evaluating groups places priority on it. Therefore whenever raising labor productivity is found to be in conflict with other goals, it is in fact sacrificed.

Another example of the same process can be seen in the interaction of different target plans. Several plans are "lowered from on high" to the foreman: technical-economic, the monthly plan broken down into days, dispatch warning signals, the labor and wage plan and so on. The foreman does not have the possibility, and sometimes even the desire, to ensure fulfillment of all of these planned targets simultaneously. Therefore he builds a unique hierarchy of intermediate goals taking the form of a hierarchy of the plans, based on their importance.

In practice, the hierarchy of planned targets is based on the degree to which their attainment is controlled and stimulated. Thus the monthly plan is stimulated by two indicators: If the monthly target is not met, the foreman forefeits the section's "progressive" bonus, and there is another bonus that is paid for rhythmicity of production--for uniform fulfillment of the monthly plan in relation to 10-day periods. This is why meeting the planned target for the month is at the top of the hierarchy and compliance with the 10-day plan is in second place. Fulfillment of the daily (shift) target is controlled only in the event that failure of the target would cause idleness of other shops. But the plant also uses a system of dispatch warning signals that are sounded when shop shut-down is threatened. In the hierarchy of plans, the dispatch warning signal stands even higher than the 10-day target, and the shift target is hardly even considered in relation to the distribution of jobs. Therefore the section's shift target is perceived not as the target plan but as a follow-up plan, used to control fulfillment of monthly and 10-day targets.

Failure of the labor and wage plan is controlled in practice only at the shop level, while exceeding the wage fund is sometimes stimulated by the workers themselves, and it facilitates fulfillment of the production plan. The labor and wage plan is accounted for only in "favorable" months, when the production plan can be fulfilled without a threat of failure, or in response to a special directive from the shop chief, when things are not going so well in other sections.

Summarizing the above, we can say that a planned assignment which is not subjected to rigid control or to moral and material stimulation does not become a target plan to the foreman. Consequently such an assignment is not included in the structure of the foreman's actions, and the associated plan loses its value. This cannot be thought of as unique to the enterprise we analyzed, since the literature often contains such examples. "The foreman places priority on parts for which production is behind.... This 'deficit' often consists of several dozen types of parts, and it may require a day's worth of the shop's capacity or even more. When this happens, for practical purposes sections find themselves doing nothing more than catching up on production of such parts. Thus the monthly plan loses its force as a distribution planning tool, and the shop works on a 'deficit' basis every day" ((17), p 21).

We can now attempt to build a general scheme of the thinking activity of a foreman drawing up a plan of action. The foreman receives the target plans, considers the opinion of evaluating groups and creates the intermediate goals. The intermediate goals assume a hierarchical structure which is determined by the hierarchy of the target plan, and at the highest level of the end goal by the evaluation given to the foreman's activity by the evaluating groups. Then the intermediate goals are met by the completion of tasks determined with regard to the particular status of the section at the moment each intermediate goal is set.

Consequently in terms of the foreman, formation of a target plan requires consideration of the unique features of goal formation in operational planning and control. This acquires special importance in the planning of automated control systems (ASU's), where the target plan is prepared by a computer, which makes it difficult to account for human factors.

Thus the ASU psychosocial support section created within the ASU division of "El'fa' is studying the literature on psychological problems of automation, consulting with the appropriate scientific institutions, conducting psychological research on a specific enterprise and applying the obtained knowledge to creation of an automated system (with the purpose of determining the structure and volume of output information on the basis of the needs of the users, accounting for the particular features of goal formation in the creation of an automated operational planning subsystem and so on).

THE ROLE OF THE PERSONALITY'S ACTIVITY IN RAISING THE EFFECTIVENESS OF AUTOMATED CONTROL

E. D. Telegina, L. A. Abramyan

Research on the place, role and functions of the individual in control systems is one of the directions of solving the complex problem of improving production control. This problem is acquiring special urgency and controversy in connection with creation of ASU's. It is entirely obvious in this case that the place of the individual in automated control systems must be different from that he had occupied in traditional systems. Which elements of managerial activity should be retained, which would have to be transformed with the goal of improving it, and in which direction should this transformation proceed? These questions could only be answered on the basis of a comprehensive, deep study of man's managerial activity and its analysis in the most diverse aspects--production, social, psychological. Only such a study could provide knowledge on its strong and weak sides.

It is already clear today that simple installation of more-complicated and more-sophisticated computers in a control system would not be enough to fully realize the idea of automated control or to ensure optimum control in organizations. If we are to eliminate the obstacles arising in the way of automation of managerial activity and the information system upon which the latter is based, we would need to first reorganize the control system itself. One example of a way suggested for improving an organizational system is to consider the requirements on the efficiency of the developed system and the rules and means of satisfying these requirements (66). In this case the organizational system is interpreted as a normative system providing managerial personnel with a package of decisions which they apply to the appropriate situations. In more general form, these ideas, worded as requirements concerned with special research on the planning of the activity of people in an ASUP, are reflected in the theory of human factors planning. If we intend to plan and specially organize the activity of the individual in an ASU, we would have to utilize knowledge on the structure of managerial activity in different systems--particularly knowledge on differences in the content and structure of this activity in traditional and automated control systems.

The complexity of this problem stems to a significant extent from the unique features of managerial activity viewed as one of the forms of mental activity. This activity includes adoption of various decisions, often nontrivial ones, which requires a creative approach. But at the same time much of all managerial activity includes steriotypic, monotonous and habitual operations--often in large volume at that. These may include arithmetic operations (in systems in which accounting operations are not mechanized and automated), operations associated with filling in or checking documents in a strictly routine fashion, and various sorts of stereotypic decisions not requiring special analysis of situations.

According to a number of authors such work makes up more than 80 percent of the activity of even highly qualified managers (64). These are precisely the sorts of managerial jobs which make it so important to automate management with the purpose of emancipating the managers, releasing them for creative labor, for which there is often simply not enough time in ordinary conditions. This problem subjectively exists and is subjectively confirmed (managers themselves complain that they are forced to work "like automatons"). But this is not the only reason to consider automation. Other no less important reasons for automating managerial activity include the difficulties of processing the increasingly greater flows of information in traditional control systems based on the simplest calculation equipment, and the impossibility of accounting for all or at least most factors, which is crucial to adoption of optimum decisions.

But at the same time the real gains from creating an ASU often turn out to be extremely modest. Many authors have specially analyzed the causes hindering automation. Thus Novikov distinguished two groups of such causes.* The first group is associated with the imperfections of general mathematical economic models and methods, which are often found to be inadequate to a concrete control system, particularly in application to the specific conditions of supply and marketing. The second group of causes stems from insufficient development of the methods of mathematical economics in relation to the supply and marketing system (64).

In a situation where the traditional information system is left intact, the structure and content of material-technical supply of the ASU do not satisfy the requirements of the methods of mathematical economics. Because the information on supply and marketing processes used in the computer is incomplete mistakes are made, decisions are unsatisfactory and, to make matters worse, many managers develop a psychological barrier compelling them to return to manual information processing and ignore computer data. In the final analysis, this means slow introduction of the computer, higher outlays associated with these delays and a certain discrediting of the idea itself of automating control.

Information systems intended to work with an ASU are created on the basis of studies conducted beforehand on information flows, document turnover and the functions of managers. Our previous research (105) showed that such studies, when performed without psychological analysis of the activity of managers, cannot fully reveal their management practices. Special psychological methods--personal interviews of workers, direct observation of their managerial activities--reveal the deeper structure of this activity and permit revelation of the methods of action and the factors regulating these actions, ones which do not lie on the

*As in Novikov's research, the concrete object of analysis of managerial activity in our research was the national economy's material-technical supply system, to include organizations from enterprises and associations to the central organs of the USSR Gosplan, the USSR Gossnab and the main supply administrations of various ministries and departments.

surface and which are often unrecognized even by the managers themselves, but which nevertheless play a large role in the effectiveness of their work.

Our analysis of human managerial activity revealed one general factor influencing the nature of this activity--the amount of activity contributed by the individual himself. When everything in the managed facility proceeds "smoothly," the individual can make do with a previously packaged set of routine decisions and methods of action taking the form of various norms. It is at this level that the individual has special need for computer assistance. However, control also presupposes the most diverse changes in the managed facility. These changes are equiprobable, and they are not always predictable. Any reorganization of the control system would only reduce their number--it would not eliminate them. The possibility that they would arise will always remain, and consequently the need for identifying them and the ability to eliminate them would remain as well--that is, the need for control would remain.

An inconsistency between the general goals of control, as perceived by the individual, and the real status of the facility he manages is what compels the individual to act. The actions the individual takes reflect his experience and his ability to make creative decisions. Through his active actions, the roots of which lie in the basis of control, the individual finds it possible to surmount many obstacles (underproduction, deviations from the norms, changes in plans and so on) on the way to achieving the goals of control.

In real life, the individual far from always displays such activity, or lives up to his possibilities and aspirations of creative management. The unique paradox that complex management problems are solved by simple methods is often noted in descriptions of the way an individual solves complex management problems. This paradox is the main reason for introducing automated control, but in it we should also seek the factors that hinder automation and the answer to the enigma of the computer's limited possibilities in a control system. The answer to this enigma is that a very significant factor is added to these simple methods, namely man's experience, knowledge and creativity (64,105). And although these processes occupy a minor place in the activity of managers in traditional systems, they are found to be so important that they make man competitive with complex automated systems.

We must keep in mind, however, that the goal of automation is to free the individual for creativity. But this does not always happen in practice: Although the individual finds himself with more time for creative work, in an automated system (one which ignores the laws of transformation of managerial activity in an ASU) its overall effectiveness declines. Rather than the anticipated flourishing of the creative activity of an individual in an ASU, we often witness one form of routine work being simply substituted by another connected with processing computer data. Such is the unexpected result of change, or more accurately, insufficient change of the content of the individual's activity in an ASU.

But why then, despite the doubtless decrease in the volume of stereotypic jobs, does automation not automatically cause a rise in the creative potential of the individual's managerial activity? The answer to this question should be sought in an examination of the psychological mechanism of creativity, in the motive forces behind creative activity, in the activity of the individual operating as one of the necessary conditions of creativity.

What sort of factors arouse man to creativity, to activity in control, and what sort of changes do they undergo in an ASU? This question can be answered by an analysis of the structure and content of managerial activity. As was noted earlier, complex management problems can be solved by simple methods, but they may also require the individual to exert his mental capabilities to the maximum. Possible changes in plans which perpetually occur, the supply interruptions that are still encountered and other factors that disturb organization require a transition from actions based on a stereotypic pattern to actions structured on the basis of an active analysis of initial situations. Finally, absence of complete correspondence between instructions on one hand, representing the basic responsibility of managers, and their real responsibilities on the other also reflects contradictions and possible uncertainties in the content of managerial activity.

One consequence of such contradictions is that managerial activity may proceed in different ways, even when the general formal requirements imposed on the results of managerial activity are satisfied as stated in the instructions. The extensive possibilities for interpreting instructions depending on the particular features of the subject of control--his qualifications, experience, knowledge, personal qualities, activity and his desire to achieve the highest results--are precisely what cause the highly significant differences in the quality of managerial activity.

Thus practically all instructions regulating the responsibilities of managers contain words such as "ensure," "achieve" and so on; but as a rule the instructions do not specify the sort of results that must be ensured, and at what level. The means and level of achievement of results are determined by the worker himself. This is precisely where his managerial experience, activity and orientation toward a particular result operate as the most important factors.

It is presumed that the requirements contained in instructions would be tailored to the real conditions before specific actions are chcsen. Every control system contains inherent factors which stimulate managerial activity "from within" and which determine its specific features.

As an example in the form of managerial labor we studied--distribution of material resources--a discrepancy between the indicators of the plan and the concrete resources available or the requirements of the consumer was usually such a factor. In this case the manager's task is to find a means for eliminating scarcities or satisfying a consumer's new requirements (if they are deemed to be suitable). This manager structures his activity on the basis of an entire system of active actions, the choice, succession and suitability of which he determines himself. As an example he may take the problem to the dispatch office, the shipping department, the sales department, the management or even "the very top" (using the words of middle-level managers). He in a sense plays the role of middle-man between the consumer and the supplier, striving to complete the plan and satisfy suitable requirements.

The choice, formation and fulfillment of all actions required in concrete situations would be possible only if the individual exhibits a certain level of activity, if he understands the significance of the overall goal, and if it is his aspiration, if it is within his personal interest to achieve the overall goals (to fulfill the delivery plan). The individual's active position, his adequate self-evaluation of his actions is one of the main regulators of managerial activity conducted at a higher level, since the individual practically always has the possibility for limiting himself to performance at a lower level.

The activity of an individual in a control system may compensate for various shortcomings in the operation of such a system: It may surmount information and material shortages. It is governed by a system of many factors and phenomena typical of the organization of all forms of labor. It may be raised by creating special stimuli accounting for the economic, production, social and psychological factors of the organization of managerial labor. Creation of such stimuli is a means for shaping the most effective motives. The general psychological teaching on motivations and on their influence on productivity (43,53,109) may be laid at the basis of stimulation, and thus it would be one of the resources by which to scientifically organize managerial labor and raise its effectiveness.

The system of motives regulating managerial activity reflects the individual's attitude toward the results of his labor and his duties, and it expresses the degree of responsibility shown toward these duties and the understanding the individual possesses of the social meaningfulness of his work.

In what way does the activity of the individual, shaped in connection with the unique features of his personality and motivations, manifest itself in managerial decision making? Personality traits and differences in the individual's attitude toward a situation, a task and the results of activity are factors upon which managerial decisions depend. However, these factors are not only never accounted for in the planning and creation of ASU's, but they also have never been a special object of study.

If we are to raise the activity of the individual, we would first have to consider the object itself and the structure of control. The tasks arising before a managerial worker may be completed at the level of the "informational language of numbers" with a consideration for the principles of optimum distribution of resources. These principles are realized in the work of the computer, which reflects a certain level of possible distribution of material resources in the ASU that leads to a particular result.

However, the individual hardly ever limits himself to solution of managerial problems at this level. He makes managerial decisions on the basis of information concerning available resources (in comparisons with planning indicators and their changes), utilizing the principles of resource distribution, or he acts in spite of them on the basis of his own subjective understanding of what a sensible distribution would be.

Management decisions based on a subjective understanding of what a sensible distribution would be might not be consistent with decisions produced by a computer in similar situations. Sometimes--when the individual makes a decision without regard to its most important consequences because he is unable to process a large quantity of information--his decisions may be inferior to computer decisions in terms of what is optimum. This is a case demonstrating the advantage of computers in control systems. But cases of another sort arise as well--when management decisions made by the individual and based on a subjective, personal interpretation of the situation, turn out to be the best. The conditions of such a situation are often such that the formal principles of what is optimum must be violated--something that a computer cannot do at present. Moreover, man can also easily change evolved stereotypes and form new principles.

It is precisely in the creative element of managerial activity that the personality component--the subject's relationship to the situation, to the conditions and to the results of his activity--acquires special significance. These factors determine whether or not the subject will continue to observe the formal principles of decision making in his activity, or follow new principles accounting for the specific features of the concrete situation. Analysis and evaluation of a situation and its conditions presuppose the ability to see and find the dominant, "key" factors within them.

As an example in normal conditions, employees of main administrations attempting to solve the problems of distributing material resources among different enterprises consider the initially planned distribution indicators, current changes in the plans, the transportation resources available, the evolved scarcities, presence of surpluses among consumers and so on. A concrete management task, for example that of determining the priorities to be placed on delivering resources to different enterprises, may be completed with a consideration for all these factors by either man or a computer. However, only man would be able to include purely personal factors in the structure of the decision.

Thus investigation of activity associated with material resource distribution problems in one of the main administrations of "Glavsnabugol'" established that managers often find it necessary, and suitable from the standpoint of production, to violate the priorities of delivering coal to consumers. According to the established hierarchy, coal is delivered on priority to the principal consumers: byproduct coke industry, electric power plants, the Ministry of Railroads and others. However, the circumstances sometimes become such that a middle-level manager might make an independent decision changing the priority of coal delivery in favor of "secondary" consumers, on the basis that the principal consumers could wait a little without detriment.

The important role of personal relationships in managerial decision making is well known in management practice, at both the supplier level and the consumer level. There is even a special system of actions which shapes the personal relationship of managers toward a particular situation. Thus for example, a letter may be received from an enterprise asking for help in organizing an emergency shipment of coal. Or a complaint may be received that the supplier was falling short of the coal delivery plan. In these cases the employee of the main administration must display an active effort to examine these issues and make the correct decision: provide coal to the first consumer and analyze the causes of nondelivery to the second.

The impact of decisions made by a main administration often depends on the activity displayed by the consumer and on the steps he takes. Precisely what steps he takes depends on the importance and urgency of the problem and on the personal relationships which influence the decision making process. Thus we find that letters and telephone conversations are often used to influence decisions; however, they are not viewed as a very effective measure. An example of a significantly more effective step would be when an enterprise director visits a supplier himself, personally. In this case we find that there is importance to precisely who it is that makes the visit, inasmuch as the goal of such visits is often to persuade a supplier (represented by a concrete person well known to the visitor) to make the needed decision, not so much on the basis of the formal principles of distribution, of which the supplier is already well aware or which could have been transmitted to him by letter, as on the basis of shaping his personal relationship toward the needs of the consumer and causing this relationship to have an effect on the decision made by the supplier.

However, the supplier must be able to implement an adopted decision, he must be able to demonstrate its adequacy. It is namely here that a personal relationship transforms into a direct motive of activity, such that the manager begins seeking out the resources and the possibilities of their redistribution--that is, it is here that he takes a number of actions that seem the most expedient in the evolved situation. It is also precisely here that we reveal the advantage of man over computer, and his leading role in control systems, both traditional and automated.

The reason many ASU's have been inadequate is that individuals have had to use computer information which did not reflect the needs and relationships of real people. Owing to this the meaningfulness of the information they received was inadequate to shape their active relationship to the object, and so their activity was limited to fulfillment of actions at the level of formal principles of organization.

Thus the generally correct idea that a transition to automated control would require reorganization of the control system itself, which would in turn require determination of what a sensibly developed system should be and the means by which this is to be taken into account in the ASU's development, may go unrealized if only the formal rules and methods of managerial decision making are utilized. If we wish the ASU to allow man's creative possibilities to reveal themselves in their fullest, when we introduce the computer into the control system we must make sure that the conditions permitting operation of the principal psychological mechanism of creativity remain.

To a significant extent the individual develops an active relationship to the object of his activity under the influence of his interpretation of the meaningfulness of the overall goal, and of its attainment in joint activity with other people. Hence we find that "infection by activity"--personal influences resulting from contact with people and from consideration of their opinions and their evaluations--is broadly employed in management practice as a means for raising activity.

Thus an individual's work with figures that reflect management processes and the state of the object of management is also associated with people, who in the final analysis form his attitude as a subject of control. It is precisely this attitude which operates as the factor responsible for transition of managerial activity to a higher level, a factor which raises its effectiveness and its creativity.

The only part of activity that is automated in ASU's is that which man himself can structure in formal terms, activity which reflects the regularity and the repeatability of management actions. However, as was demonstrated above, the individual's understanding of the meaningfulness of events and his personal relationships to them and to people associated with them are the motives of this activity's most creative part.

Formation of subjective relationships is often not considered in modern ASU's; it is unforeseen in the organization of the new type of human managerial activity. People using computer data in an ASU find themselves excluded from the system. They deal with objectivized, impersonalized information that does reflect real, concrete people. This excludes an entire area of motives regulating development of the individual's activity and creativity in management, which naturally cannot but have an influence on the effectiveness of automated systems and on the individual's evaluation of his place within them.

If we are to capitalize upon the individual's activity with the purpose of raising the effectiveness of management decisions, we would have to purposefully develop the personality. The main thing we would need to do is to shape a special motivation--the individual's understanding of the social meaningfulness of the events associated with any decision he makes. We would also need to raise his sense of responsibility and capitalize on the system of values and relationships of other people toward his managerial activity.

An analysis of cases of low effectiveness of some ASU's would show that managers become less active, they become indifferent, their decisions become uncreative, and their sense of personal responsibility decreases whenever the computer information with which they must deal does not reflect real people and their relationship toward it. Such "dehumanized" information is unable to stimulate people to make management decisions at a higher, creative level, to perform additional actions (ones not specified in instructions) and to display creativity.

Typically, individuals who have had to work with such computer information have tried to surmount its negative influence on their own. Once again, their effort to surmount this influence entailed inclusion of contacts with people into their activity. Thus on receiving computer information about a control process, the individual telephones the enterprise to receive it a second time, "first hand." This duplicates the work of the computer, and naturally it should be interpreted as a harmful factor in the work of the ASU. However, despite the fact that the individual must perform some additional work, he feels it to be justified, since in addition to gaining objective information he also learns the subjective attitude felt toward it by other people, which permits him to form his own system of attitudes. These attitudes are then included in his own managerial activity, into his management decisions.

Thus a computer must be used in optimum fashion in an ASU: It must operate as an assistant to the individual, and it must not substitute completely for other people, it must not displace contacts with them. Their attitudes, opinions and evaluations must be evident behind all computer information, and they should be utilized in the making of management decisions.

The theory of human relationships in organization and in management, developed by Soviet social psychology, describes numerous forms of interaction among people at different rungs of the hierarchical ladder of control as factors promoting growth in the productivity of managerial labor. These forms include creation of a positive psychological climate within the collective, creation of positive mutual relationships between supervisor and subordinates, joint managerial decision making and formulation of new management goals on the basis of communication and interaction between people (29,58,65).

The individual's understanding of his place within the structure of the joint activity of people in an automated control system, consideration of their evaluations of and relationships to the results of the individual's labor and consideration of these evaluations and relationships in the individual's work are among the necessary prerequisites of organizing the individual's managerial activity in an ASU, and of ensuring his activity as a subject of control.

PART III
THE PROSPECTS FOR BRINGING 'ARTIFICIAL INTELLIGENCE' CLOSER TO HUMAN INTELLIGENCE

THE PSYCHOLOGY OF THINKING AND THE PROBLEMS OF CREATING 'ARTIFICIAL INTELLIGENCE'

Ye. S. Kuzin

Most researchers concerned with creating "artificial intelligence" formulate different definitions of it and then base the orientation of their further work on these definitions. The main reason why there is no agreement on how this term is understood lies in the diffuseness of interpretations applied to the concept "intelligence." Clarifying the nature of intelligence and its role in the life and activity of a biological system is the priority task of scholars in the natural sciences, and mainly psychologists. I believe that a definition of intelligence must avoid the two extremes: "mechanization"--that is, attempts at describing it with the help of parameters typically applied to machines--on one hand, and its definition solely on the basis of the features of human activity on the other.

Therefore the goal of efforts to create "artificial intelligence" is not to recreate natural intelligence together with all of its unique features, but to develop a certain automatic system performing specific functions of intelligence. At the same time, creation of such a system must be based on comprehensive research on thinking by psychology, physiology, linguistics, philosophy, and so on, or attempts to simulate the typical traits of its organization. However, when we pose the issue in this way we impose higher requirements on this research, since only distinct conclusions and definitions can serve as the foundation of further work. Work on "artificial intelligence" meanwhile, should itself continue in parallel with this research, growing richer from the latter and posing new problems. In this case automatic (artificial) systems should simulate primarily those aspects of natural intelligence which appear most fundamental today.

We based the research described in this article on two typical features of the organization of thinking: its comprehensibility and possession of a certain system of knowledge by the individual.

Operation with the content of concepts reflecting elements of the problematic environment and their interaction plays the fundamental role in thinking. Numerous works have been devoted to this aspect of thinking.

The fundamental importance of comprehensibility, "which is inherent to memorization, to recall and to the organization itself of the search for a solution to a problem," is emphasized in Tikhomirov's last work (91).

As a result of creation of a mental model of the objective world by the subject, each concept (mental discharge) acquires its semantic content through association with other concepts in the model. The appearance of a new meaning is the result of some sort of transformation in the model, and it is equivalent to arisal of new knowledge. Revelation of the semantic content of a concept and the search for elements of the required meaning on the basis of conceptual associations make up the basis of the thinking process.

Rubinshteyn (81) points out that analysis of each element of a problem depends on the associations of which it is a factor and which are determined by the relationship between this element and the requirements of the problem. The results of thinking are included into the thinking process itself and, enriching it, they govern its subsequent course.

Tikhomirov words the importance of analyzing the semantic content of concepts during thinking very clearly (92): "One of the most important characteristics of problem solving is that the meanings of certain elements of the situation undergo development. Meaning is the result of a certain group of retrieval operations; meaning develops by the inclusion of the same element into different systems of interactions." Tikhomirov interprets the entire course of problem solving as a search aimed at analyzing the semantic relationships of elements in different situations and conducted within the subject's system of knowledge. In this case presence of elements with particular properties in the situation is anticipated, and the need for such elements, referred to as the need of "retrieval," is created.

Thus one requirement an "artificial intelligence" system necessarily imposes on an internal model of the objective world is its comprehensible reflection of the content of elements in the problematic environment--both the initial content and that formed by the system in the course of problem solving. The potential for examining each element in terms of any meaning that may be required by the problem solving process--that is, the possibility for "exhausting" (using Rubinshteyn's term (81)) its semantic content--must be ensured. In each stage of problem solving, each element within the problematic environment must have only a certain "operational meaning" different in the general case from its "operational meanings" in other stages of solution. In this case the system must ensure a number of degrees of freedom that is maximum possible for the given hardware, and a broad possibility for voluntary reduction of the degrees of freedom.

One fundamental feature of the way the subject perceives the objective world is its representation in the form of a single system of knowledge, one appearing as an integral set of knowledge. This means that the semantic content of any concept within this set may be expressed only by way of all other concepts within this set as a whole. No concept, no individual item of knowledge can be interpreted in isolation; when abstracted from this system, it ceases to exist. Every concept has its own personal meaning to the individual, a meaning that is a product of the entire system of his knowledge.

The individual's system of knowledge is defined by his environment, by what he does in this environment, and it bears an oriented nature in the broad sense of this word. However, the orientation of its organization cannot be represented as a set of general models of situations and variants of behavior corresponding to them. Such organization is limited in nature, and it may be interpreted as only a particular case. In fact, when we perceive knowledge to be organized in terms of different situations, the situation appears as an integral element having particular semantic content. The elements of the situation, meanwhile, play the role of characteristics which permit us to distinguish one situation from another. The system's reactions would be adequate in this case only in the event that the concrete situation can be identified with one of the reflections of the situations already present in the system's memory.

Within a system of knowledge, the meaning of any situation is revealed as the result of an analysis of the semantic content of its elements, and the system's behavior in the given situation is the result of a synthesis performed on the basis of this analysis. In this case adequate behavior may be organized even if a new situation is encountered (a "new" situation is defined as one whose elements are already known to the system but which are encountered for the first time in the particular relationships).

Reproduction, in an automatic system, of the integral structure of a system of knowledge, together with the undisturbed organization of semantic associations between its elements, is in our opinion the first step on the road to creating artificial intelligence systems.

One such attempt was development of the principles of representing this system of knowledge in a computer during creation of an automatic system capable of searching for the paths of problem solution. The main parts of the system are the model of the problematic environment (MPE)--a program containing the sum total of mutually associated items of information about the environment, and a set of reasoning schemes (RS)--a program containing the sum total of schemes for organizing "thinking" during the system's solution of various problems. The method of organizing the solution process in this system was named the meaning retrieval method (MRM). Knowledge is represented basically in the MPE as a programmed organization taking the form of an integral structure consisting of different elements and the associations among them.

When these programs are run in the computer, each element appears as a set of computer words. All the words (except auxiliary or working words) have identical structure: Some of the bits of each word indicate the address of one of the elements with which the given element is associated, and the rest of the bits indicate the nature of the associations between these elements. Each such association is two-sided. Thus the potential is ensured for moving on the basis of these associations from one element to another in any direction, and if a certain strategy for such movement is developed, a possibility for organizing directed retrieval within the structure is ensured.

The system of knowledge is represented within this word structure in such a way that each element would correspond to a certain concept of the system of knowledge; in this case some of the concepts (relationships) may exist as both elements and associations simultaneously.

On the whole, the described structure forms the memory, organized according to the associative principle, as it is defined in computer technology--that is, the search for the needed elements is organized not on the basis of *a priori* assignment of addresses but rather on the basis of assignment of their semantic content.

This structure affords a possibility for using a broad class of various problem-oriented languages based on natural language. The model of the problematic environment may also include specialized complexes of knowledge having different structural organization and expressed in the corresponding formal languages. To maintain the integrity of the system of knowledge and its semantic unity, these complexes must include concepts definable within the main structure, since they must themselves fit within this structure as individual concepts.

One indisputable merit of the MPE is its open-endedness and the simplicity of inclusion of new concepts. New concepts are introduced by definition, using the appropriate semantic associations with concepts already present in the system of knowledge.

The reasoning schemes, also included in the system of knowledge, perform retrieval and the necessary transformations in the MPE. Such transformations can include formation and incorporation of new concepts in the MPE, addition of further detail to the structure of existing concepts, representation of new relationships between concepts in the MPE and so on.

Each of these reasoning schemes represents a certain *a priori* strategy controlling retrieval in the MPE and, consequently, its transformation. The form of strategy, and thus the type of reasoning scheme as well, depend on the particular task (for example the tasks of planning, demonstration, determination of laws and so on), and for practical purposes they do not depend on the problematic environment. In distinction from knowledge in the MPE, knowledge contained in the RS is expressed only in imperative form, as in conventional computer programs (that is, a set of unconditional and conditional commands).

An RS is a sequence of steps of semantic search (search based on given semantic associations), formed *a priori*. The result of each step in the search is retrieval of a concept possessing a semantic content necessary for continuation of the solution process, or the conclusion that such a concept does not exist (at least in the given search direction). After each step of the search (or after a determined sequence of steps), the RS contains a command for a conditional transition that switches the reasoning process, depending on the results of the search at the given stage, to some new retrieval step.

Following completion of the stages of the search, as governed by the RS, the reasoning scheme makes the appropriate transformations in the MPE, after which new stages of the search begin, ending with new transformations, and so on.

Special emphasis should be laid on the fact that each specific mental step in the structure of the MPE depends on two factors: on one hand the order built into the RS and, on the other, the semantic relationships of the concepts--that is, their semantic content. The principal motive of retrieval is the "need to retrieve"--the need to find an element possessing the needed properties. The "need to retrieve" itself arises as a result of an inconsistency between the representations of the target and current situations in the model of the problematic environment. The desire to eliminate arising inconsistencies encourages a search, following a strategy contained in the RS, for operators responsible for transformation of the problematic environment, perception, calculation and so on.

Several variants of models for different problematic environments have been examined thus far, development of a language for describing the problematic environment in relation to one class of problems is now coming to an end, and one of the variants of a planning algorithm designed for series YeS EVM computers is now being run.

'ARTIFICIAL INTELLIGENCE' AND THE STRATEGY OF ANALYZING THE COGNITIVE STRUCTURES OF NATURAL INTELLIGENCE

L. M. Vekker

Research on the "artificial intelligence" problem is limited today to the possibilities for technically reproducing various types and forms of human cognitive processes at the level of just general computer codes. There is good reason for this, since at this universal level the organization of the information structures of "artificial" and natural intelligence adheres to common principles. This is precisely why the present method embodies within itself the theory and technique of modeling intelligence at the level of elementary information processes--that is, operations with symbols. However, this universal level far from exhausts the entire diversity of concrete information structures. Further movement forward in research on "artificial intelligence" is being restrained by the status of the psychological theory of natural intelligence.

In the psychological theory of cognitive processes, meanwhile, two diametrically opposite points o. view are pitted against each other. One of them are used for interpretation of different forms of cognitive processes by various systems of concepts and by the terms of various scientific languages (psychophysics, the theory of perceptual gestalts, logical-linguistic conceptions of thinking). On the other pole we are encouraged to erase the boundaries between intelligence, thinking, perception and the mind in general, and consequently to blend the initial and derivative forms of cognitive processes together. This significantly distorts the picture of mental structures pertaining to both lower and higher forms of cognitive processes. In regard to elementary forms of cognitive processes, such equalization of initial and derivative levels expresses itself, for example, as the very widespread tendency to deduce the features of the spatial-temporal structure, objectivity, constancy and integrity of perceptual images from the degree of their comprehensibility, of their realization, from the nature of word meanings and so on.

This tendency is significantly amplified by the fact that forms of organization of information processes that are more-particular than what can be expressed at the general computer code level are typical of perceptual images. This is why revealing the information laws governing this organization is so much more difficult. As a consequence we arrive at a paradoxical empirical-theoretical situation in which all of the basic characteristics and laws of the spatial-temporal organization of cognitive structures existing at different levels (from the level of sensations to that of conceptual thinking) are artificially focused only on the perceptual sphere, which represents only the middle layer of the hierarchy of the levels of intelligence.

Both the lower-lying, specifically sensory level and the overlying general level of thinking, and all the more so the conceptual level, are thus "made immune" to the general laws of spatial-temporal organization of cognitive information structures.

Such distortion of the empirical picture expresses itself in regard to sensations mainly in that the reflection of the location in space of a sensed object is separated from the representation of the spatial coordinate grid within which this reflection must exist. Contrary to elementary logic, problems associated with reflection of object locations are treated in most studies and even textbooks as pertaining to the sensory level, while representation of the space within which this object is located is treated as being at the specifically perceptual level. To move on, in regard to the thinking level of intelligence this deformation expresses itself in that thinking processes turn out to be generally immune to the laws of spatial-temporal organization of cognitive structures. These laws and characteristics of spatial-temporal organization of thinking processes are said to be somewhere "beneath thinking," divorced from the principles of its specific organization.

We find in this case that while isolation of the more-general structures of the intellectual hierarchy from the elementary structures, to which specific genetic steps correspond, is commonly said to impermissible, the much more artificial operation of "liberating" the overlying structures from fundamental generic structures is said to be totally natural and permissible. All of these deformations in the natural relationships existing among intellectual structures are the inevitable consequence of the blending of their initial and derivative forms.

If we are to surmount this accepted but false premise, we would have to determine the specific features of the initial and derivative levels of cognitive processes within the framework of the general laws governing their organization. These general laws are considered by the modern general cybernetic (non-Shannon) theory of human information processing. On this basis, the specific features of different particular structures of intelligence must be revealed within the framework of the general principles of the organization of information processes.

Revelation of the specific features of the particular principles of organization existing within the general principles would require a special strategy resting on the genetic approach and on the method of abstract "extirpation" of overlying layers. This method allows us to reveal the specific characteristics and laws of each of the forms and levels of cognitive processes, and to reveal the means of their synthesis, from "below" and from "above," into the integral structure of natural intelligence.

This strategy permits us to represent, within the framework of common organizational principles, different particular forms of the information structures of cognitive processes, existing at different levels (elementary sensations, perceptual and secondary images, mental structures, and the highest form--conceptual thought), as different levels of mental reflection, each having its own measure, form and range of constancy of reproduction of the properties and relationships of reflected objects.

Thus according to the extensive empirical material of Akishiga's scale (and our data (28)), the spatial-temporal organization of sensory processes conforms to the level of the partial metric invariant, perceptual images are the integral metric invariant, and transitory forms of the sensory-perceptual domain and secondary images are different levels of spatial-temporal invariants (starting at topological, proceeding through projective and affine to the level of invariants of similitude transformations, and finally, metric invariance).

The large number of facts provided by experimental and applied psychology provide the grounds for concluding that the specific features of thinking processes are determined by interaction of symbolic operator structures of external or internal speech with spatial-objective gestalts. The facts show that these spatial schemes are not just the descriptive basis of thought but also an internally necessary component of its organization.

Contemporary general theory permits us to represent these spatial-objective components of thinking on one hand and the symbolic components of its spoken form on the other as different languages in the general cybernetic meaning of this concept--that is, as different particular forms of informational and code structures isomorphic to their source objects.

On this basis the specific organization of human thinking may be represented as a continuous process of reversible translation from a language of simultaneous spatial-objective representations (pertaining to different levels of generality) into the symbolic operator language of speech symbols. Then a thought, viewed as a separate structural unit, would be the result and the invariant of this process of interlingual translation.

Theoretical analysis supported by experimental verification allows the conclusion that within the framework of this general principle of the informational structure of thinking, a concept is unique in that this reversible translation from the language of simultaneous spatial gestalts into the symbolic language of speech signals occurs at a minimum of two levels of generality (generic and specific). Then a concept, viewed as a separate structural unit of thought at the highest level of intelligence, would appear as an invariant of the transformation of the levels of generality into a process of interlingual translation.

Experimental research (28) specially undertaken to verify these premises has shown that there are specific relationships in each of the examined forms of cognitive processes between informational (structural and statistical) characteristics, their energy equivalents and their operational composition. In the first approximation, the empirically obtained relationships correspond to the theoretical expectations.

Inasmuch as this strategy allows us to reveal the universal spatial-temporal components of these hierarchically different structures--components which pass from the bottom to the very top of the hierarchy, we are able to examine the methods of synthesis of these different cognitive levels, "from the bottom up," into the integral hierarchical structure of natural intelligence. It is only after revealing the specific nature of the structure, invariance and the operational composition of the concept--viewed as the highest layer of this hierarchy--that we are able to clarify the regulatory and organizing influence this highest level has on elementary cognitive processes, and thus uncover the methods of synthesis, "from the top down," of this set of levels into an integrally functioning system.

Thus natural intelligence viewed as an integrally functioning construct is a hierarchical system consisting of many levels. Its function is based on continuous interaction of two languages: simultaneous spatial-objective structures, and the symbolic operator language of speech signals. When one of these languages, which are a part of the principle itself of integral organization of natural intelligence, ceases to function, the intelligence stops working normally not only at levels pertaining to the excluded language but also to the entire set of cognitive processes contained within the integral bilingual structure of intelligence.

Clear evidence of this can be found, for example, in the clinical pattern of semantic aphasia, in which the speech and thinking functions of intelligence are disturbed as a result of lesion of the parieto-occiptal lobes of the cortex, with which not the language of the speech signals themselves but the first of the two languages of natural intelligence--the language of simultaneous spatial-objective gestalts--is associated.

Were we to exclude the language of speech signals from an integrally functioning bilingual system, we would obtain a purely perceptual level of cognitive processes. But--and this is especially important--if the language of simultaneous spatial-objective gestalts is excluded from this system, we would arrive at the general coded form of information processes, that which we see in modern technical information systems. Being in keeping with the present potentials of "artificial intelligence," it unites natural and "artificial intelligence" on the basis of a single general cybernetic principle of organization.

Thus further development of the theory and hardware of "artificial intelligence," which will proceed along the lines of simulation of natural intelligence, should be ensured by reproduction of the mechanisms having to do with both information languages, the interaction of which predetermines the specific features of the integral operation of human intelligence. The greatest theoretical, experimental and technical difficulties existing at this stage are elicited by simulation of those cognitive information structures which are embodied within the particular forms of the codes, and which pertain to the first of the languages of natural intelligence--the language of simultaneous spatial-objective images.

THE POSSIBILITIES OF COMPUTER MODELING OF DESCRIPTIVE AND CONCEPTUAL THINKING

Yu. V. Orfeyev

When researchers consider the philosophical aspects of modeling thinking, they do not devote enough attention to how well descriptive thinking yields to computer modeling; this is despite the fact that the limited nature of the methods of information modeling (which is discrete by its very nature) manifests itself more clearly here than in information modeling of logical problem solving, in relation to which visual images may not play a significant role in searching for the solution.

From the standpoint of genetic psychology, the structures of conceptual thinking, which are by their nature interpsychic, arise in the ontogenesis of the child on the basis of previously developed capabilities for operating with images of surrounding objects. Even in early childhood the infant is capable of recognizing the faces of people surrounding him, food and toys. In abnormally developed children, ones suffering mild retardation for example, the capability for operating with images does not depend on the level of intellectual development. The same can also be said for animals, which are capable of actively using images of the environment to organize their behavior, but which are generally devoid of conceptual thinking.

Descriptive thinking is a special form of manifestation of intelligent behavior, as is conceptual thinking, which develops within the individual as he masters symbolic activity. It would be interesting to note that modern writing and the ideographic writing that preceded it developed out of symbols--pictures. Some hieroglyphics still possess clear descriptive similarity to the object they represent.

In human thinking activity, the descriptive and conceptual components are closely associated, and they interact with each other actively. In his time, Rubinshteyn wrote in this regard that being different levels or stages of cognition, descriptive and abstract-theoretical thinking are in a certain sense different aspects of the same process and are equally adequate methods of cognition of different aspects of objective reality (80).

Were we to examine human thinking only within the sphere of the exact sciences, in which the level of abstract-theoretical thinking is naturally high, even here we would find that images play the decisive role in the initial stage of the creative process.* Einstein wrote the following in this regard in his creative autobiography:

*It will be interesting to cite Meshcheryakov in this connection: "...real thinking is never reduced to operation with symbols--of which gestures and words are representatives in a certain sense; instead, it always presupposes operations with the images of objects and actions" (60).

"To me, there is no doubt that our thinking proceeds for the most part in disregard of symbols (words) and, moreover, unconsciously. Were it to be otherwise, why would we sometimes be 'surprised,' and quite spontaneously at that, by a certain experience (Erlebnis)? The 'act of surprise' apparently occurs when perception enters into conflict with our established world of concepts. In those cases where this conflict is experienced acutely and intensively, it in turn has a strong influence on our mental world" (109).

Both discursive and descriptive thinking have their spheres and limits of effectiveness. One class of problems might be solved more easily with reliance upon visual models, while another class of problems might not be solved effectively with these models, and in this case discursive thinking would have indisputable advantages. Descriptive thinking may lead to gross errors if the problem to be solved is outside the directly perceived sequence of events. But in cases where the solution to a problem can be deduced from the organization itself of the "visual field," using the terminology of Gestalt psychologists, visual-descriptive thinking would have doubtless advantages over discursive thinking.

Beginning in the 1950's energetic efforts were undertaken in cybernetics to teach computers to recognize visual images. An essentially integral direction came into being in cybernetics--so-called image recognition.* However, the problems which are actually solved by the methods of "image recognition" are not equivalent to the problems associated with image perception. The main task of a computer recognizing images is to relate a certain object characterized by a set of features to a certain class--that is, its task is classification, while the psychological problem of perceiving an object as a result of active objective actions with it cannot be solved by the methods of cybernetic recognition of images.** From a psychological point of view object classification is preceded at least by the object's perception and recognition (18). In fact, in order to recognize some mineral, we would first have to perceive it as an object. Manipulating this object, we can establish for example that it is granite. And it is only after recognizing the object that we could identify it. Of course, under certain conditions of human activity perception may be reduced to the process of identification.*** In a large library, for example,

*The term "image recognition," commonly used in Soviet cybernetic literature and apparently synonymous with the English expression "pattern recognition," would best be substituted by the term "image classification," since the latter term better reflects the essence of the computer task; moreover the English word "pattern" may also be interpreted as meaning "model."

**"If an individual is to form the image of a thing that reflects its objective properties," Meshcheryakov writes, "he would have to perform some sort of practical action in relation to it. Simple perception of a thing without practical influence upon it does not provide a possibility for penetrating deeply into its essence" (60).

***A criminal may be arrested on the basis of both a verbal description and by confrontation. In the first case we would need a list of the criminal's features, while when he is recognized by a witness this list would not be needed. Identification by means of a verbal description in many ways recalls the principles of recognition embodied within the existing computer programs, while identification on the basis of confrontation is not yet within the means of a computer.

only the numerical code of a book would provide information as to its location, and librarians may pay attention neither to the name of the book nor to its appearance.*

In the methods of image recognition known today, all sorts of clever procedures are used to separate the characteristics of one image from another--for example the compactness hypothesis, and projection of characteristics onto a subspace. However, all of these methods presuppose, in one way or another, the possibility for distinguishing a certain set of characteristics and relating them to a previously given, fixed list of characteristics or a standard.**

The difference between human recognition and the behavior of a computer "recognizing images" is fundamental in nature. Simple external properties of objects such as straightness, cohesiveness and so on cannot be given to a computer directly; instead, they must be reproduced by a complex system of equations which would allow the computer to verify coordinates of appropriate points in order to determine whether or not it is dealing with a straight line or a curve. A computer cannot show preference for one combination of figures over another if it had not previously been given the characteristics on which to base a preference. At the same time, an individual making a choice between one combination of figures and another usually follows unverbalizable esthetic criteria. A computer can do the same only in the event that the methods of classification are clearly written out.

Practical use of cybernetic methods of identification is made complex by the fact that, first of all, it is often difficult to say precisely what the significant characteristics of an object are, and second, there are no grounds for the assumption

*It would be interesting to note in this connection that three means of perception were distinguished in ancient Indian philosophy (Nyaya philosophy). The first means--(nirvakal'naka)--signified recognition of the simple existence of a thing without a distinct impression of it and of its characteristics. For example a person immersed in his own thoughts might take a bath without once thinking about the water as water. Nevertheless it cannot be said that the water was not perceived while bathing. In the second means of perception an object is viewed as a thing of a special sort; this means is called (savikal'paka). Thus for example, looking at an orange, I say to myself the conclusion: "This is an orange." In this case I not only recognize its existence as such, but I also distinctly understand that it exists, at least within my perception. The third means--(prat'yabkhidzhnya)--signifies recognition of an object as something known to us. For example: "This must be that same person who shoved me yesterday" (102).

In European psychology this classification may correspond to concepts such as perception, recognition and identification.

**Among cybernetics, Shannon most clearly recognized the entire complexity of solving the problem of image recognition by modern computers. He said: "...machines that could effectively solve such problems as pattern recognition, translation from one language to another and so on would require a type of computer that we do not have today. It seems to me that these would be computers capable of performing natural operations with patterns, concepts and fuzzy analogies, and not successive operations with decimal numbers" (Shannon's presentation at the debate "What Will Computers Be Able To Do?" is published in the collection (122)). However, no one knows yet how machines that could operate with "fuzzy analogies" should be organized.

that characteristics making A similar to B and B similar to C would be the same that make A similar to C. There may be no noticeable similartity between A and C and, moreover, they may still be similar to B. An object is placed in one class or another not on the basis of its properties but rather on the basis of the classification goals.

In order to delve more deeply into these problems, we would need to acquaint ourselves with the existing psychological theories of perception. Perception psychology usually makes a distinction between successive and simultaneous recognition. In order to demonstrate the fundamental difference in their mechanisms, we will examine a few examples.*

Any literate person is capable of recognizing handwritten letters, but at the same time he would be unable to identify the characteristics on the basis of which this recognition proceeds. This is precisely why it is impossible to come up with a necessary and sufficient list of characteristics for handwritten letters; modern computers can dependably recognize only type which is structured to some extent, and not handwriting. Much effort has been expended on making a machine capable of perceiving any handwritten text, but no significant progress has yet been made.

The difficulty of this problem apparently lies not only in the fact that simultaneous recognition cannot be substituted by conceptual recognition in the perception of handwritten letters, but also in the fact that under normal conditions recognition of the graphic elements of handwritten letters depends on context--that is, the adjacent letters of a word contribute to recognition, and in a number of cases the entire context of a statement is taken into account. As an example the word "kelp," when handwritten, may be read as both "kelp" and "help"--it all depends on the broader context which the individual unconsciously considers.

The same can also be said for recognition of handwritten graphic elements such as: 10%. These graphic elements may be recognized as the number 10010, or as 10%, or as three letters O separated by vertical lines and so on.

Thus for recognition of handwritten text, there is no minimum of graphic elements (the building blocks of a text) upon which we could rely. Correct recognition depends on interpretation of the "building blocks" at each level of linguistic description (letter, phoneme, sentence, statement).

On the other hand if a civilized individual must distinguish a 20-story building from a 21-story building of the same height, or distinguish a polygon with 20 sides from a polygon with 19 sides, in this case the particular image would have to possess distinct characteristics, and simultaneous perception would be ineffective in such cases. A computer may surpass man in solution of such problems if the number of characteristics necessary for identification is sufficiently large.

*"Simultaneous recognition," writes M. S. Shekhter, "includes integration of several characteristics (of the appropriate sensory information, to be more precise) into one indivisible unit, as a result of which the object is evaluated in accordance with a single perceptual characteristic and not on the basis of several corresponding to different properties of objects" (107).

The difference between simultaneous and successive recognition is fundamental in nature. Numerous psychological studies of perception processes have shown that simultaneous perception is not a reduced, swiftly proceeding version of successive perception, but a mental process of a special type, one based on considering the "appearance" of a figure and the "shape" of the figure as a whole, perceiving the context and background, and so on. In other words this is recognition based on integral characteristics, owing to which perception of the whole anticipates perception of the parts--that is, the parts are determined only after perception of the whole.

Perception psychology interprets simultaneous recognition as activity performed without successive analysis of the perceived object. In the process of training (learning), successive recognition transforms into simultaneous recognition, but for such a transition to occur, the individual's consciousness must contain an ideal plan, which is a specifically human form of reflection of reality.*

The simultaneous perception problem is closely associated with the presence, in man's perception, of unconscious reflection of objects in surrounding reality; experiments with subsensory perception may provide experimental confirmation of its presence. We are well aware of experiments of the following sort, for example: The subject is successively shown sets of nonsense syllables. When some of them appear, the subject is given an electric shock. The subject develops a reflex as the experiment proceeds: Whenever a certain syllable appears, he gets a presentiment of an electric shock. The subject cannot explain (verbalize) the characteristics of the symbol which produces this presentiment (146).

Another good example of unconscious reflection is the well known stereoscopic effect that arises when one looks at two almost identical images through special glasses. Such reflection is also observed with auditory and tactile stimuli (33).

Thus unconscious reflection, manifested as simultaneous perception with a Gestalt nature, plays a certain role in perception of objects and their relationship. As we know, to recognize objects, a computer can operate only with a formalized knowledge of them. Presence of unconscious, unformalizable knowledge about external objects is precisely the main obstacle to progress in image recognition by computers.

In addition to dividing perception into simultaneous and successive (conceptual), perception psychology sometimes draws a distinction between cognitive and operational images. Cognitive images are a unique sort of storehouse in which all information about an object accessible to the subject is concentrated.

Operational images are those which arise in the course of practical manipulations of objects aimed specifically at solving certain problems.

Although cyberneticists have enjoyed certain successes in creation of the methods of recognizing cognitive images, the problem of forming operational images in

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*Psychopathology is well familiar with agnosia associated with disturbed simultaneous recognition; in this case object recognition may occur only with reliance upon successive recognition.

modern computers is still not soluble within the limits of this methodology. The data of phenomenological psychology indicating the mobility of the boundaries between the body of the subject and the "external world" surrounding him attests to the great complexity of forming an operational image. Thus parts of the individual's own body may sometimes be perceived as part of the "internal world" and at other times as part of the "external world" depending on the conditions of perception.

As an example when an individual pares his nails, the hand performing this procedure would belong to the "internal world" while the other would belong to the "external world." In other cases the reverse may be true: Part of that which we usually treat as belonging to the "external world" becomes included in the "internal world." As an example everyone who has ever ridden in a motor vehicle knows that during the time in which he is operating the motor vehicle, the driver's "external world" begins with the outer surface of the cab. The same effects are also observed in piloting an aircraft. Consequently the boundary between subject and object may be mobile in an operational image.

The mobility of the subject-object boundary is also at the basis of the objectivity of our perception. In fact, from the standpoint of the cybernetic theory of image recognition it would be difficult to explain the objectivity of images.

According to the cybernetic conception of visual perception, an object to be recognized must at first be somewhere within the subject, and later on, by means of an act of reflection or by some other mechanisms, it is carried outward and related to reality. Such a receptor conception of perception is being experimentally refuted by all developments in experimental psychology.

The mobility of subject-object boundaries allows us to give a deeper explanation of the objectivity of visual perception, something which has long been at the focus of attention of Marxist philosophy: "...when light from a thing stimulates the visual nerve, this stimulus is perceived not as subjective stimulation of the visual nerve itself but rather as the objective form of the thing that is outside the eye" ((1), p 82).

In order to understand this point we would need to turn to the way a cane (probe) is used to feel out the way in darkness. At first, while moving in darkness with a cane the individual would sense jarring in the palm and fingers whenever the cane touches some object lying on the path. But as experience accumulates (as happens with blind people), these jars transform into the sensation of certain objects outside the individual. Moreover these subsidiary sensations, as Polanyi refers to them, on being integrated by our body, acquire a certain meaning to us as signals of objects lying along our path (149).

Something similar also happens in visual perception which, as we know, is based on interiorized sensomotor schemes of locomotion and of manipulation of objects. In visual perception, the role of a probe (feeler) is played by beam of light, owing to which our sensations shift in such a way as to create objectively perceived images.

This interpretation of the objectivity of visual images can be traced back to Sechenov, who wrote the following in this regard: "In this sense the act of looking may be likened to the body's release of feelers which can lengthen and shorten to enormous proportions in such a way that their free ends, on converging with one another, would come in contact with the objects being examined at the given instant. Without stretching the point at all, we could then perceive the visual axes to be such contractile feelers" ((84), p 521).

In addition to these facts, which are usually not taken into account in cybernetic modeling of perception, there are also facts indicating perception's close relationship to emotions and to sensory anticipation of a perceived object.

The examples above show how far afield the principles used in automatic image recognition are from the real processes of human perception. Nevertheless, cyberneticists have proposed a number of important technical procedures for image recognition, and this fact cannot be forgotten. The existing practice of image recognition has assumed the path of joint solution of these problems by man and computer in "dialogue" mode. In these conditions man's unique capabilities are not excluded from recognition, and on the other hand the hardware supplements and amplifies these capabilities. Tangible practical results have been achieved along this path.

The problem of image recognition by computers is also posed in cybernetic literature as one of automatic formation of concepts, if the objects subject to classification cannot be visually interpreted. A typical example of attempts at using a computer to form concepts can be found in the works of Khant (99) and Benerdzhi (18). But even here, success in the initial phase of use of the methods is supplanted by disenchantment as soon as the need arises for applying them to formation of concepts in more-complex situations.

Khant interpreted concept formation in the following way:

1) Objects are those real elements which may be observed by the "subject" (a person or an artificial concept forming system). The set of all objects makes up the general set;

2) objects may be distinguished in terms of the significance of their characteristics. Thus each characteristic is a degree of freedom in the qualitative differences of objects;

3) the description of an object is an indication of its status, as determined by the observed characteristics;

4) the set of quantitative characteristics which may be interpreted as being equivalent is represented by a certain value;

5) the description space is the set of all possible descriptions of objects.

If we look at the concept forming methods used in "computer thinking" from a philosophical point of view, these methods would in fact be traceable back to the purely empirical understanding of abstraction which we can find in the works of Locke and Mill. The theoretical aspect of concept formation was first addressed in philosophy by Plato, who clearly recognized the entire complexity of this problem.

How do we identify objects, how do we relate them to a certain class when every object differs from another? In his dialogue with the priest Euthyphro, Socrates demands a clear and unambiguous definition of piety. Euthyphro tries to clarify the definition of piety, but each of his proposals is criticized and refuted by Socrates, since all of Euthyphro's definitions are only "accidences"--modes of the idea of piety, while what Socrates requires of Euthyphro is the idea itself of piety (68). The fight between nominalism and realism in Middle-Age philosophy is also a reflection of the complex philosophical problems which require theoretical analysis of man's concept formation for their solution.

The crisis which the cybernetic approach to formation of concepts by computers now faces was in a certain sense anticipated by the criticism of the weak sides of the empirical theory of abstraction in the works of Kant, Fichte, Hegel and Husserl. As we know, Husserl meticulously criticized the empirical theory of abstraction, according to which a generality arises in the subject's consciousness on the basis of a comparison of similar characteristics.

Husserl felt that if that which is common is to be perceived in objects, a special intentional act is needed, in which the consciousness must be directed not at concrete objects but rather at the idea by means of which the objects surrounding the individual are generalized. Husserl felt that when a person recognizes objects, he introduces a universal meaning (the noeme) in his interpretation of his sensory data (14). In other words image recognition and concept formation would be impossible without a certain ideal plan.

L. Vitgenshteyn and other representatives of linguistic philosophy also criticized a simplified understanding of the nature of abstraction and explained the danger harbored by such an understanding. Vitgenshteyn suggested the conception of "family similarities" as an alternative to the traditional theory of abstraction. Vitgenshteyn asserts that the idea behind the characteristic facial traits of a family member could be transmitted by showing "family portraits" (cited in (19)). From Vitgenshteyn's point of view man is able to recognize a family member without going through the list of characteristics on which he achieved such recognition.

The concept formation problem is analyzed to its deepest extent in Marxist philosophy on the basis of the dialectics of the singular or special and the general. Il'yenkov clearly stated the problem of the universal: "The radical-materialistic reinterpretation of the achievements of Hegelian logic (dialectics) by Marx, Engels and Lenin is associated with confirmation of the objective reality of the universal, though not at all in the spirit of Plato and Hegel. It is associated more likely with the natural relationship existing between material phenomena, with the law of their linkage into a certain whole, into a self-developing totality, all of the components of which are essentially 'kindred' not because they all have the same, identical characteristic but rather in view of the unity of their genesis..." ((46), p 256).

An analysis of the empirical theory of abstraction in which concepts were interpreted as a disjunctive-conjunctive combination of the characteristics of objects was subjected to sharp criticism by Lenin in connection with the party's debate on trade unions in the early 1920's. Lenin wrote: "The formal logic to which instruction is limited in the schools (and should be limited--with corrections--to the lowest grades) works with formal definitions, using as its guidelines that which is most usual or that which catches the eye most frequently, and it limits itself to this. If in this case two or more different definitions are taken and joined together quite by chance (a glass cylinder and a drinking implement), we get an eclectic definition indicating nothing more than different sides of the object.

"Dialectical logic requires that we go farther. In order to in fact know the object, we must embrace and study all of its sides, all of its associations and 'intimations'" ((4), pp 289-290).

We can see from all of this that in "computer thinking," the concept is interpreted only as a combination of characteristics isolated from a set of objects under examination--that is, that it is at the level of the empirical theory of abstraction. At the same time the problem of forming theoretical concepts cannot be solved in "computer thinking." Hence we can understand that the concept forming procedures used in "computer thinking" have a limited sphere of practical application for the moment, and that further progress in this sphere may be ensured only through "dialogue" interaction between man and computer.

PHONEME DISCRIMINATION OPERATIONS IN ORAL AND MENTAL ACTIONS

Ye. N. Vinarskaya

We are well aware of Lenin's premise that "sensation, thought and consciousness are the highest products of material organized in a special way" (2). Therefore if achievement of the strategic goal--approaching human intelligence more closely--would be impossible if we ignore or limit our use of the data of psychological science on human intelligence (50), achievement of this goal would also be impossible if we fail to take account of the data of neurology--the science studying the structural and functional relationships of the brain and the neurophysiological equivalents of the mind.

V. I. Lenin also pointed out that beyond the limits of gnoseological studies, "operating with the opposition of matter and spirit, of the physical and the mental as with an absolute opposite would be an enormous mistake" (3). Leont'yev (55) discussed some types of relationships between the material and the ideal in application to thinking. I believe interaction between the neurophysiological and psychological aspects of thinking to be significant. Various psychological operations are supported by neurophysiological activity of not the brain in general but certain of its structural units. Knowledge of the systemic structure of neurophysiological mechanisms could help us understand the structure of psychological processes.

This communication briefly presents some ideas about the operational structure of verbal thinking stemming from psycholinguistic observations of patients with selective defects in systemic organization of their neurophysiological processes. The theoretical premises will be illustrated by excerpts from the observation notes for one of our patients.

Here are the initial neurophysiological facts.

Patients of the group described here suffer focal lesions in the mediotemporal subregion of the cortex of the dominant hemisphere, coupled with breakdown of functional integrations in which the nerve cells of this region of the cortex play the leading role. The degree of the brain's focal dysfunction could change in the course of observation of the patient, but the effect of its presence remains constant. The activity of the integral brain proceeds invariably in the presence of the same systemic defect.

More or less pronounced disturbances in speech perception are observed among all patients in connection with such focal brain lesions. These disturbances are expressed as substitutions, transpositions and omissions of the consonants and vowels of phonemes (ul'i--"uyli," tsokol'--"chokol'," kareta--"raketa," berloga--"bergruga, bekroga, bekloga" and so on).

The disturbance of psycholinguistic operations supporting perception of the adequate phoneme structure of oral symbols leads to a situation in which the patient ceases to understand the speech of surrounding individuals. The statements of the patients themselves contain a sizeably larger number of homonyms, since oral symbols with different meanings are expressed as having the same meaning (in view of insufficient differentiation of phonemes). As an example the phonemic form of the words "grozovoy, legka, Kronshtadtskiy" is not differentiated from the phonemic form of the words "gruzovoy, legla, grazhdanskiy." Naturally, surrounding individuals cease to understand the speech of such patients.

Patients experience the greatest difficulties in perceiving verbal symbols having phonemic composition similar to that of other verbal symbols, especially if both are also characterized by similar morphological structure and are used in similar semantic context.

"What is a karavay [bun]?"

"It is something to sleep on (the word'krovat' [bed] is presumed)."

"Explain what this sentence means: 'On poluchil nozhevuyu nozhnuyu ranu [He received a knife leg wound]'."

(The patient thinks.) "No, I don't understand it."

"But what if I said that he received a knife wound in the leg?"

"Well, that I can understand."

That was precisely what the first sentence meant.

However, there is an exclusion to the general rule stated above: words with a pronounced objective relationship used in situationally dependent dialogue. Patients can not only understand such words well, but they can also pronounce them correctly. Monologue statements on abstract topics are beyond the capabilities of the patients.

Patients do not understand various inflections, prefixes, suffixes, prepositions and linking verbs totally devoid of objective relationships when they are uttered in the speech of surrounding individuals, and they ignore them in their own speech, which makes it strikingly agrammatical. Thus the following statement was typical of the patient: "Ona stala chitat' knigu. Vot ona. [She began reading the book . There she is] (Points to a women in the office). This I can understand. Reading--that I can understand also. (Mimics the act of reading). A book--here is a book (points to a book). But why is the word began here? What is began? I don't understand."

If they have visual-descriptive correlates, lexical and grammatical symbols are used adequately by patients in their speech. Thus an analysis of mistakes in linking adjectivesto nouns in nominative case ("bol'shaya plamya, veselyy karusel', sladkaya kisel', moya klyuch, chernyy ten'") showed that such grammatical mistakes occur only when the gender of the noun is a conditional grammatical abstraction, one expressed moreover by a phonemic structure of low probability for a morpheme of the given gender.

Wherever the grammatical gender of a noun is consistent with the biological sex of the object under discussion, no difficulties arise. ("Man is masculine, meaning that you would say bol'shoy muzhchina; cow, of course, is feminine, meaning you would say ryzhaya korova" and so on). Nor do mistakes arise when the phonemic expression of a gender-related morpheme is highly probable for words of masculine, feminine and neuter gender. ("Basket is feminine, so you say bol'shaya; lake and milk are, of course, neuter and so lake is bol'shoye and milk is beloye; cabinet is masculine, so you say seryy; chair is also masculine, so you say novyy.").

In psychology, Vygotskiy (31) brought attention to the symbolic nature of thinking done in words. Zvegintsev (43) explained the close relationship between verbal thinking and speech by the operational use of the same symbols, formed under the influence of language, in both processes. Using special observations which will be described below, I would like to not only confirm the symbolic similarity of speech and verbal thinking but also demonstrate the identical nature of disturbances in usage of symbols in both speech and thinking associated with verbal concepts.

The first thing that comes to mind is that patients always try to relate verbal concepts to their sensory images. ("Why is a cat called a 'cat'? Why is a table called a 'table'? Why is a white flower called a 'rose'? This is 'rose'." (Points to a rose-colored pencil.)

Narrating the content of stories that they had heard and movies they had seen, patients use verbal concepts to describe only the train of their own descriptive impressions, and they do not make use of any abstract verbal concepts reflecting, in symbolic form, the relationships of the characters, the reasons behind their acts and the general meaning of the occurring events. (Here is the way a scene from a motion picture was described by a patient who found this scene disturbing. In it, drunken thugs murdered a young man who had come to the aid of a girl: "He approached her. They smiled at each other. Then another three fellows came up. They staggered about.... They began making threats, and then they murdered him.")

While being able to classify pictures of objects (furniture, china, animals) and verbal concepts having visual-descriptive correlates, patients become confused when they try to classify abstract verbal concepts.

Patients readily perform assignments involving selection of antonymic concepts of a concrete sort (black-white, fast-slow, night-day), but they cannot do the exact same thing when they are offered abstract concepts. In this case it is sometimes evident that the difficulties lie in finding that same phoneme form of a verbal concept. Thus when asked to provide a concept opposite to that expressed by the word "proletariat," our patient replied: "I know that it is some word beginning with 'c'." "Capitalist?" "Yes, that's what I thought."

While they can easily solve arithmetic problems involving from one to three manipulations, patients suddenly cease performing such assignments if words having similar phonemic compositions are introduced into the problem conditions. Thus our patient was able to solve the following problem in his mind as he listened to it: "A boy has five apples; a girl gave him another ten, such that he now had three times fewer apples than the girl. How many apples did the children have together?" The patient was unable to solve the problem stated with different numbers and with the words "boy and girl" substituted by the names "Sanya Petrov and Tanya Petrova."

To sum up, only those concepts and conclusions which have clear visual-descriptive correlates were retained in both the verbal thinking and the speech of the patients. Verbal thinking in abstract concepts is impossible for such patients, as are monologs on abstract topics. Visual-descriptive thinking and verbal thinking proceeding in parallel visual images were retained, as was situationally dependent dialogue speech.

An individual's verbal thinking is disturbed, first of all, to the extent that it is expressed in abstract verbal concepts or, more precisely, in abstract linguistic (lexical and grammatical) concepts and, second, depending on the structure of phonemic generalizations making up the symbols of these linguistic concepts. Inasmuch as one of the axioms of linguistics declares that any linguistic symbol is a two-sided mental entity, the data of our research are easily explained.

The clinical pattern of the focal brain lesions tells us that each of the components of the singular mental essence of linguistic symbols has its specific neurophysiological correlate, and that each neurophysiological correlate of a particular psycholinguistic component may be disturbed selectively, leading to various systemic disorders in the speech and intellectual behavior of the individual.

The bionic conclusions: Thinking in abstract verbal concepts and speech apparently have not only a common dependence upon symbols but also common psycholinguistic mechanisms. Sequences of phonemic generalizations making up the appropriate symbols occupy a certain place within the system of psycholinguistic units, and they exist in complex structural relationships with them.

This must be accounted for when developing "artificial intelligence" systems, so that the intellectual possibilities of these systems would be more commensurate with human possibilities. Failure to account for complex systemic relationships on the psycholinguistic plane (the phonemic forms of linguistic symbols in this case) would have an especially tangible impact in regard to creation of man-machine complexes requiring interaction between man and machine in natural human language.

'ARTIFICIAL INTELLIGENCE' AND DECISION MAKING

V. F. Rubakhin

"Artificial intelligence" is one of the pressing and complex problems of the modern science of cognition.

Usually when we create "artificial intelligence" systems, we single out two different forms of supporting software--methodological support, to include the use of heuristic, logical-algebraic, linguistic, bionic and other methods, and modeling support, to include informational and algorithmic programming support. We should obviously add to this, and raise to paramount importance, psychological support.

The USSR Academy of Sciences Institute of Psychology, the Academy of Pedagogical Sciences Institute of General and Pedagogical Psychology, the Moscow State University and Leningrad State University psychological departments and other scientific institutions are presently studying the psychological aspects of the "artificial intelligence" problem. This research is being performed basically in four directions:

study of the relationships between formalizable and unformalizable components of natural intelligence;

investigation of the structures and mechanisms of decision making;

analysis of the ways and possibilities of formalizing mental processes;

study of the possibilities of creating adaptive man-machine or biotechnical systems, including hybrid systems.

One of the most important stages and the key moment of existence of any complex system is the decision making act. Even a robot must make decisions concerned with, for example, the choice of the route to travel to a goal or of the means for surmounting an obstacle. In this case the most interesting structures are supplied with subroutines in which the possible variants are played out beforehand, a plan of operations is drawn up and the expected result is predicted. In its "behavior," we recognize many traits typical of human behavior and, concurrently, profound, fundamental differences in the processes of mental regulation, ones having no analogs in "artificial intelligence" programs. Motives, emotions, will, and moral-ethical norms are absent from modern "artificial intelligence" devices.

The differences between the organization of human mental processes and the structure of the behavioral programs of robots become distinctly evident when we compare functionally kindred processes, for example the processes of recognition.

The structure of recognition algorithms contained in "artificial intelligence" systems is in a sense organized in a single plane: The particular way in which an algorithm is run depends directly on the problem at hand or the goal posed. While decision making on the basis of numerous criteria would require algorithms of greater complexity, it would not alter the fundamental structure of the regulatory processes themselves.

Man's processes of perception and recognition, including procedures associated with decision making at this level, are different in nature. The stages of informational preparation for a decision and of decision making itself may be described in general form as follows:

Information preparation to decision making boils down to procedures falling into two groups: a) retrieval, isolation, classification and generalization of information on the problematic situation; b) creation of "current" images or operational conceptual models. The decision making procedure may be described by the following operations: a) initial suggestion of a system of "reference hypotheses"; b) comparison of "current" images with a series of standards and evaluation of the similarity between them; c) correction of the images (models), "adjustment" of the hypotheses in relation to the results; d) selection of the "reference hypothesis" (or its derivation).

Now let us examine particular laws on the basis of different experimental approaches.

B. F. Lomov and his colleagues undertook an experiment to study formation of a perceptual image during perception of an assortment of figures--an arbitrary combination of straight lines and curves. The conditions of the experiment (exposure time, observation range, figure illumination) were varied in such a way that the process of the image's formation would be expanded to the maximum.

In all three variants of the experiments, certain general traits were observed in the dynamics behind formation of the perceptual image. In the first phase the perceptual image reflects the position of the figure within the field of vision relative to the principal spatial coordinate, its overall dimensions and proportions and its basic color. In the second phase the most striking turns in the outline of the figure and its basic (largest) details are reflected; the color characteristics of the figure are determined more specifically at this time. The figure's small details are distinguished and traits revealed earlier are defined more specifically in the third phase. Formation of an adequate image is completed and the image is verified in the fourth phase.

Thus intensive analytical-synthetic activity and discrimination of different characteristics of the object in different phases are significant psychological characteristics of the development of a perceptual image and of the retrieval operations supporting its development.

We obtained similar information in research on perception and recognition of complex objects (images on a noise background).

Our experimental research on perception of such noisy images permitted us to suggest the hypothesis that perception and recognition under these conditions has a combined "layered-stepped" nature. According to this hypothesis, solution of such a problem would include the following processes:

a) "layer-by-layer" analysis--preparation of the structure of the images in a succession from layers representing large elements to layers representing small elements;

b) stepped-phasal processing of information within one layer involving the running of several cycles of analytic-synthetic procedures;

c) formation, "at the output" of the layers, of intermediate images that are subsequently integrated into the final image;

d) comparison of these images with a standard having different information content, and determination of the standard isomorphic to the current image.

We conducted experimental research on perception and recognition of photographic images of lone and grouped objects on a noise background in order to clarify the specific laws governing solution of such problems. Our "test objects" were small-scale photographs of airplane silhouettes characterized by different degrees of resolution. The alphabet consisted of 18 stimuli with 10 degrees of resolution (from 7 to 40 lines/mm). The procedure required recognition of the noisy images one at a time, beginning with the lowest levels of resolution, presented in random order.

Two levels of information processing were established experimentally: "topological" and "categorical." The following sublevels can be distinguished in the first (add up to 10 lines/mm): a) grouping of indistinct "spots" by their dimensions; b) grouping of indistinct images by their "topology"; c) their differentiation within a group. At the second level (over 10 lines/mm), the subjects distinguish sublevels of the grouping anddifferentiation of the configurations of the objects as semantic "constructs" in application to their classes (subclasses) and types--that is, the objects are determined more concretely layer by layer.

Work with the grouped images showed that when an image is significantly disturbed by noise, the loss of its elements may be compensated by the use of external interference-resistant indicators as well as by activation of ideas (imagination) and thinking. This process now goes beyond the limits of the image's resolution, but it can lead to the goal--recognition.

We found that the process of perceptual study of objects within the limits of the revealed layers has the character of an expanded search, and that to one extent or another it makes use of information from previous experience.

The results of another series of experiments showed that the process of recognizing the images of simple objects is entirely different. This process is abridged, it does not have clearly distinguishable phases, and it relies on other methods of examination and on other operational units of perception. Recognition is typified by a sharp reduction of the number of revealed traits and retention of a certain set of introductory components. This minimization is expressed externally as immediate concentration upon the axis of symmetry or the center of the figure, as exclusion of a number of areas from the analysis, as more-ordered inspection of the remaining areas, as use of a limited number of fixation points and as sharp reduction of returns to points already inspected. This process is directly connected with a predictive procedure. Internally, minimization boils down to using other combinations of characteristics resulting from their isolation, enlargement and subsequent semantic coding. Naturally these acts of recognition may proceed in other time frames as well.

As we had noted earlier, decision making at the level of perception and recognition includes the operations of deriving and selecting hypotheses and comparing them with the formed image of the object.

To clarify the general dynamics of hypothesis derivation in complex conditions, we conducted experiments of greater detail to study recognition of the photographic images of geometric figures on a noise background. There were 12 degrees of resolution (from 5 to 35 lines/mm), and different exposure times were employed (from 0.3 to 1.5 sec).

The experiments showed that the hypothesis is derived and chosen under these conditions in accordance with the principle of progressive classification. The subject works through several hierarchical steps of varying information content, corresponding to the layers (information levels) of the "layered-stepped model." In general form, recognition proceeds from levels with very high entropy to levels with limited information content.

As the resolution and structural integrity of the image rise, the number of hypotheses (the alphabet of standards) at the given level undergoes a general decline.

It may be hypothesized that in multiple recognition, the object is compared each time with different systems of "standards" (alphabets) depending on the phase of image formation in which the comparison is made. An analysis of the experimental data revealed the fact that subjects never make their choice in strict correspondence with the code tree. They in a sense skip steps: As they proceed from certain categories to others, they limit themselves each time to comparison of the perceptual image only with an insignificant number of "standards," changing the characteristics upon which to make the comparison as the process goes on.

It may be presumed from the research of a number of authors that standards are associated with different alphabets in the individual's memory. The same "standard" may exist as an element of many alphabets. Standards are generalizing in nature. Owing to this, the alphabets overlap, which makes reduction of the path taken in search of "standards" during recognition possible. The individual need not sort through all elements of each alphabet.

Thus decision making processes are characterized by the following features at the level of perception and recognition, especially when decision making proceeds in difficult conditions.

1. Both in the phase of information retrieval and formation of the perceptual image and in the phase of decision making itself, these processes have a productive nature, expressed in: constant inclusion of the object of recognition in new systems of associations through analytical-synthetic activity (the alphabet of characteristics undergoes change; it exhibits a "sliding" nature); change in the level of generality of the characteristics of the objects under examination (transition from perceptual characteristics to semantic ones, enlargement of the operational units of perception), and so on.

2. The decision making procedure itself proceeds to a significant extent not on the basis of actualization and sorting but rather on the basis of hypothesis derivation. This appears very significant to us, inasmuch as selection of and sorting through hypotheses are typical of decision making in most of our research on decision making.

3. The content of the decision making phase is determined by the nature of the formed perceptual image. In other words in actualization and selection of hypotheses, the particular features of the image ensure selectivity in actualization of specific hypotheses.

Returning to the problem of building "artificial intelligence" systems, we must once again emphasize that the structure of human perceptual and recognition decision making described very briefly here is far more complex than that of recognition processes built into cybernetic devices.

With time, however, some of the phases and procedures of recognition revealed in psychological experiments may be realized in computer form.

CONCLUSION

In the opinion of a number of authoritative scholars, creation of "artificial intelligence" is the most complex scientific-technical problem of all that have ever been addressed by mankind. The contemporary literature on "artificial intelligence" problems is typified both by acutely critical statements directed at "artificial intelligence" and by no less acute criticism of this criticism. For example B. V. Biryukov believes that Dreyfus' critical assessment of the prospects for development of "artificial intelligence" "has not passed the test of time."* In Biryukov's opinion we now know the answer to the question as to "how far we can go on the road of computer simulation of the functions and structures of the living and the intelligent.... There is a vast no-man's land between modern heuristic automatons and the specifically human sphere, inaccessible to computer reproduction."** The criticism of the critics of "artificial intelligence" is sometimes qualified as misconceptions associated with the programming of "artificial intelligence."

From the psychologist's point of view the modern literature contains misconceptions not only relative to "artificial intelligence" but also relative to human intelligence.

The first misconception is associated with the assertion that computer programs embody the same methods of arriving at decisions (corrected to be compatible with the high speed of computers) which are used by man (heuristic programming). In fact, however, informal search methods, which include emotional isolation of the zones to be searched, and the motive governing this search are not reproduced in heuristic programs.

The second misconception lies in the assertion that the behavior of self-teaching and self-improving systems of any complexity whatsoever may be expressed as a list of rules that may be represented in the form of computer programs. Self-development of the personality, for example, cannot be reduced to clear rules, since it includes generation and resolution of conflict situations having solutions for which there are no fixed rules.

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*Dreyfus, Kh., "Chego ne mogut vychislitel'nyye mashiny" [What Computers Can't Do], Moscow, PROGRESS, 1978, p 303.
**Ibid., p 329.

The third misconception is contained in the assertion that the process of posing new problems follows clear rules that may be revealed and programmed. Psychological studies have shown that in addition to logical rules, processes associated with detection of contradictions play a significant role in the posing of these new problems.

The fourth misconception is the assumption that the rules of intelligent activity function separately from human emotions and "traits of character." The principle of the unity of affect and intelligence, according to which the real function of human intelligence is subordinated to laws of the affective sphere as well, has been around a long time in psychology.

The fifth misconception is that emotional evaluations are identical to verbal-logical evaluations; in fact, these are qualitatively different phenomena. This misconception generates the illusion that there would be no difficulties in embodying man's emotional sphere within the work of computer programs.

The sixth misconception boils down to the suggestion that manifestations of intelligence ("phenomenology") are independent of its internal structure ("mental apparatus"). However, this independence is relative, since different manifestations of intelligence seen in the child and the adult and in the normal individual and the sick person are usually the product of differences in intelligence structure (dominance of visual-active thinking over verbal-logical thinking in the child, change in motivational regulation of thinking in a sick person, and so on). Moreover the same external manifestations of intelligence may differ in psychological content. Thus even though the word "table" may be recognized as referring to the same objects, it may have different significance and different personal meanings to different individuals.

The seventh misconception is the opinion that direct simulation of the brain is the sole alternative to the phenomenological approach. Intelligence is in fact a function of the brain, but we also know that the brain (the healthy brain) does not uniquely determine the content and structure of the individual's activity, which is formed under the influence of social and cultural factors, and at a certain stage of development, under the influence of the conscious efforts of the thinking individual.

In my opinion by surmounting these misconceptions concerning the nature of human intelligence we will be able to discuss the possibilities and concrete ways of creating "artificial intelligence" in greater detail and more substantially.

Developing Glushkov's idea that "there is fundamentally nothing hindering us from creating 'artificial intelligence' that is significantly superior to natural human intelligence,"* Ivakhnenko and Kostenko assert that human psychology can really develop only after we create a general theory of superintelligence. In other words human intelligence could be understood more fully only after we study the laws of <u>superintelligence</u>--the next step in the evolution of intelligence.**

*Gulshkov, V. M., "Cybernetics and Artificial Intelligence," in "Kibernetika i dialektika" [Cybernetics and Dialectics], Moscow, Nauka, 1978, p 181.

**Ivakhnenko, A. G., and Kostenko, Yu. V., "The Possible and the Impossible in Intelligence Simulation," AVTOMATIKA, No 6, 1978, pp 75-82.

This premise, which casts the gauntlet before psychologists, gives birth to the following fundamental question: In terms of what parameters should we expect "artificial intelligence" to be "superior" ("better") than human intelligence? Human intelligence is distinguished into different forms--visual-objective, visual-descriptive and verbal-logical. These different forms coexist in the adult, and it cannot be said of any one of them that it is absolutely superior to the others irrespective of the type of problem at hand. We need to clarify the particular type of problem in relation to which we hope to achieve "superiority" in "artificial intelligence."

The function of human intelligence is always regulated by a system of motives, the most important ones of which are those associated with studying the essence of objects. Might we expect that "superintelligence" would possess qualitatively new, more-sophisticated motivation? Without human emotions, there would be no distortion of truth. Might we expect that "superintelligence" would possess a more delicate, more sophisticated form of emotional regulation than human intelligence? One of the most important functions of intelligence is to pose new goals. Might we expect that "superintelligence" would be capable of posing more-sophisticated goals, "supergoals"? If the answer to these questions were yes, then we would have to show how possible it would really be to endow "artificial intelligence" with these properties, at least in elementary, primitive form, so that dreams about "superintelligence" would transform into scientifically grounded experimental realities. But if the answer to these questions were no, the impression would arise that human intelligence will have to be "surpassed" not in relation to those indicators which characterize its true essence, and therefore there would be no grounds for thinking that "artificial superintelligence" would be able to understand the essence of human intelligence, since the former would simply be lacking the most significant characteristics of the latter.

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